The effect of catch shares strength on management of marine resources

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"It is not true that we humans are rational beings par excellence. We are emotional beings who use reason to justify or hide the emotions which drive our actions."

Humberto Maturana

Chilean biologist and philosopher

DECLARATIONS

Statement of originality

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Statement of Ethical Conduct

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

Statement of co-authorship

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Author 3 assisted with general statistical and coding advice.

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ABSTRACT

Catch shares or Individual Transferable Quotas (ITQs) are economic instruments used in fisheries to address common pool problems. They attempt to increase economic yield from the fishery by allocating exclusive and secure fishing rights and by promoting catch constraints that will lead to stock rebuilding. The catch shares are transferable, which results in a market for both sales and temporary leasing of quotas within the fishery. Fishers are expected to make their decisions in line with good stewardship practices because they benefit from future improvements in the stock, and efficiency of harvesting increases as quota is transferred to more efficient operators. There is empirical evidence that some successes towards these goals has been achieved by ITQs, such as fleet rationalization, however, some issues arise when fishers do not behave as expected. Therefore, knowing how fisheries respond to ITQs and how the incentives change with changing stock abundances is critical in assisting fisheries managers when designing polices. In this thesis the total allowable catch (TAC) setting process in Australian and New Zealand ITQ fisheries were analysed to identify factors that prevent fishers exercising good stewardship. The Tasmanian rock lobster fishery (TRLF) was then used as a case study to analyse the sale and lease quota market. Changes in quota transfers and interactions between operators in response to changes in stock abundance were assessed. Finally, an experimental economic approach was used to assess factors that may promote cooperation when restocking is used as a tool to address stock and congestion externalities that result in spatial stock heterogeneity. The aim of the thesis was get a higher understanding of factors that may prevent expected outcomes emerging from ITQ systems.

A fundamental and expected outcome of ITQ systems is resource stewardship through the setting of conservative TACs. This is anticipated to be promoted by increase in catch share values that results from higher catch rates, in combination with security and exclusivity. Despite most of the analysed fisheries behaving as expected, a non-trivial fraction consistently showed lack of stewardship, keeping constant and even

increasing the TACs when stock status and asset values were trending downward. Several reasons were identified as a cause of this behaviour, the most frequent being a lack of understanding or acceptance of the principle underlying the ITQ systems. For instance, TAC constraints were interpreted as a reduction in profitability which indicated no understanding or value placed on the economic benefit of higher future catch rates. This analysis showed that despite the fact that stewardship is possible in ITQ fisheries, it is not inevitable and additional conditions are required to promote stewardship.

Stock abundance can change as a consequence of a lack of stewardship and/or natural causes such as recruitment failures. This can potentially be reflected in the quota markets, as they are expected to respond to variations in economic rent from the fishery. Since the ITQ system was introduced in the TRLF, the stock has shown two periods of trends in abundance - a period of stock growth between 1998 and 2006, followed by a period of stock decline between 2007 and 2011. These changes affected quota markets in the fishery with a trend of increasing activity in the permanent quota trade market during the period of stock growth and during both periods in the quota lease market. The transfer of quota units was not associated with the operators' technical efficiency (i.e. catching capability) as predicted for ITQ fisheries, but linked to their financial capacity (i.e. number of owned quota units). The stock decline changed fishers' behaviour, with those previously active reducing their activity in the quota lease market, and those inactive becoming involved in the market, resulting in an expanding fleet with more small operators.

Stock abundance changes also affected the lease quota trade network with increased interactions during the period of stock growth, which lasted until the second year of the period of stock decline. Individuals had greatest level of connection (traded quotas) with other fishers at this time, following which the trend reversed as the stock declined. The social capital of active operators and position in the lease quota trade network was mostly influenced by the fishing operation characteristics, and by quota ownership in the case of investors. Different dimensions of social capital influenced the success of operators in the fisher and caused them to modify their trading interactions in response to changes in stock abundance. There were some indications of asymmetry in bargaining power, such as between small and large quota owners and this relationship changed when the stock declined and the lease quota trade market became less competitive.

In addition to temporal variations, stock may vary spatially in terms of abundance and/or resource quality. ITQ systems do not delineate who can fish in each specific patch; therefore, fishers target more profitable areas, which generates stock and congestion externalities. An economic experiment was used to assess the effect of different factors promoting cooperation, including when restocking was used to address stock and congestion externalities and the consequent rent dissipation. When policies involved compulsory actions and economic punishment some extent of cooperation was reached. The highest level of cooperation occurred when the policy design gave the option of choosing between getting involved in the restocking plan or not. Nonetheless, evidence showed that the voluntary option should be complemented with a measure that provided those individuals who are intrinsically cooperative with security that those liable to free-riding are either physically excluded from or punished for fishing in the restocked area. When the design only included a voluntary setting, free-riders dominated. Thus, depending on signals conveyed by the rules, intrinsically cooperative individuals may lead the economic exchanges to an equilibrium of low rent dissipation and vice versa.

This research makes a contribution to the discussion of factors that affect fishers' decisions, and how in some cases these decisions prevent expected outcomes of the ITQ system. This provides guidance on the design of management policies in the context of ITQ systems.

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Chapter 1

General Introduction

1.1. Right-based management and individual transferable quota systems

Right-based management instruments, such as Individual Transferable Quota (ITQ) systems are used in fisheries to pursue economic rationalization and efficiency through two main mechanisms. Namely, allocation of private fishing rights to operators and through market-based incentives (Wilen 2006). Under ITQ systems, fishers are provided with an exclusive and secure access to catch shares or quota from a Total Allowable Catch (TAC) of a given stock. This fishing right is expected to remove incentives to compete for fish, because fishers do not need to invest excessive capital to maximize catch given the guaranteed catch share. The consequences are fleet rationalization and fishing effort reduction, which are expected to improve the fishery profitability (Dupont *et al.* 2002, 2005; Fox *et al.* 2003, 2006). When TACs are soundly set stocks remain abundant or rebuild when they are depleted with a subsequent increase of catch per unit of effort (CPUE). Thus economic efficiency is gained by minimizing cost and maximizing profit (Arnason 1990; Wilen 2006; Costello *et al.* 2010).

The market-based incentive of ITQs relates to wealth creation from the traded value of catch shares. The market value of these shares is expected to reflect the net present value of future cash flows from each catch shares (Wilen 2006). Catch shares are an intangible asset and their value (price) should increase in response to higher profits such as from lower fishing costs as a consequence of stock rebuilding and higher catch rates. Thus, quota price is positively correlated with good management (Batstone and Sharp 2003; Newell *et al.* 2005) and an indirect measure of stock status (Arnason

1990). Capitalization is expected to provide incentive for stewardship of resources, "Ownership refers to the stewardship incentive that is designed into ITQ systems to motivate share owners to care for long-term resource use" (Garrity 2011). However, the link between allocation of catch shares and stewardship is rather speculative. In fact, in the few attempts to prove this link the results showed that private rights do not necessarily promote stewardship (Gilmour *et al.* 2011, 2012). It is clearer that a functional market for quota transfers is critical for establishing a link between capitalization and stock status. In the presence of functional markets, quotas are expected to transit to more efficient operators, and operators who have higher fishing costs are expected to exit the fishery with compensation from the quota sale. Thus, the market is expected to increase overall fleet efficiency (Branch *et al.* 2006).

ITQ systems have had positive outcomes in many fisheries around the world. For instance, based on a long time series from a global database of catch statistics, it was reported that the stock collapse risk was lower than average in fisheries with ITQ-based management (Costello *et al.* 2008). Other outcomes identified following the introduction of right-based management include improvement in economic efficiency (Pascoe *et al.* 2011; Grimm *et al.* 2012); extension in the length of the fishing seasons and thus continuity of supply (Casey *et al.* 1995); and improvement in the quality of product (Bonzon *et al.* 2013). Relaxation of input controls in fisheries with ITQ-based management has also led to cost reduction, due to elimination of inefficient controls such as catch limits per trip and seasonal closures (Weninger and Waters 2003).

Despite these positive outcomes, ITQ systems have also received criticism on the basis of ecological, economic and social concerns (Costello *et al.* 2010). Ecological issues include the incentive for high-grading, which results in discard and mortality of lower-market value fish (Copes 1986), and also concentration of effort into spatial areas where product has a higher unit value (Bradshaw 2004). From a socio-economic point of view, criticism has been directed at quota concentration (REF), unequal bargaining power amongst quota owners and the excessive cost of quota units that creates a barrier to new entrants or business expansion (Pinkerton and Edwards 2009). Finally, economic issues emerge if ITQs do not delineate where fishers may harvest; therefore they often concentrate their effort on more profitable patches reducing overall economic yield from the resource (Boyce 1992). This problem arises because competition between individuals remains and may lead to congestion externalities such as gear conflict and loss of product quality (Costello and Deacon 2007).

1.2. Individual transferable quota system in the Tasmanian rock lobster fishery

The ITQ system management system was introduced in the Tasmanian rock lobster fisher (TRLF) in 1998 in response to declining stock productivity (Bradshaw 2004). This declining trend could not be reverted by input control management, as it failed to reduce overcapitalization and fishing effort (Ford 2001). The TAC is set annually and equally split into 10,507 quota units. These quota units were distributed solely on ownership of licences, with no account of catch history. There is no minimum quota ownership, but units can only be fished if associated with a fishing license holding a minimum of 15 units with five of these to be owned by the license holder (the remainder can be leased in). There is also a maximum quota-holding limit of 200 units designed to prevent concentration of ownership, which is an unusual aspect of the quota system in this fishery. Markets for both sale and temporary lease of quota units have developed with the number of participants, the number of transactions and the connectedness of the market increasing through time (van Putten *et al.* 2011).

Once the ITQ system was implemented, the fishery went through an initial period of stock rebuilding with a trend of increasing biomass and catch rates until 2006. Over this period, the TAC was harvested each year, quota lease prices rose (Gardner *et al.* 2011) and the fleet reduced in size from 239 active vessels in 2000 down to 203 in 2007 (Emery *et al.* 2014a). These trends reversed from 2007 with biomass and CPUE declining as a result of a period of below-average recruitment (Linnane *et al.* 2010b). The TAC was not fully taken in 2009 and catch rate decreased by 34.2% from 2006 to 2011. This decline in stock resulted in lower lease prices (Gardner *et al.* 2011), which created an incentive for new entrants (lease fishers) and the fleet size increased with 33 more vessels reporting catch in 2011/12 than in 2006/07 (Hartmann et al. 2013).

1.3. Research objectives and thesis structure

The overall aim of this research was to carry out a quantitative assessment of the strength of the ITQ system, by analysing fishers' behaviour under conditions of stock biomass changes and discussing patterns relative to what may be expected according to ITQ theory.

The thesis is organized around four core research chapters and two appendices that include two articles additional articles. The candidate is co-author in these additional articles based on substantive contribution in the analysis of data, which was a similar method and research topic to that dealt with in chapter 5 of this thesis.

According to the economic theory associated with ITQ systems, the allocation of exclusive fishing access should create incentives for resource stewardship. It is expected that quota owners should support and advocate for TAC constraint in pursuit of higher economic yield from the cost reduction that occurs with stock rebuilding and higher catch rates. In **Chapter 2,** the history of TAC setting was explored in several ITQ managed coastal fisheries in Australia and New Zealand. The objective was to examine whether TACs have been constrained to target higher profitability and thus increase asset values as predicted by ITQ theory. When the historical pattern in decision-making was not in line with the expected pattern, the potential factors that may explain these results were explored.

Transferability of quotas is another component of ITQ systems that is expected to have net positive outcomes for the fishery, with the rationale that quotas are expected to transit from less to more efficient operators. Quota transition requires a functional market that values future economic yield and this is true for both quota sales and temporary quota leasing. Changes in the stock abundance are expected to be reflected in the economic rent from the fishery and consequently in the quota markets. The dramatic changes in stock productivity that occurred in this fishery provided an opportunity to assess the functioning of the ITQ quota market and whether expected outputs, such as quota flow to more efficient operators, remained during biomass decline (**Chapter 3**). In **Chapter 4,** this effect of biomass change was further explored in an assessment of the functionality of the lease quota trade market by analysing the structure and dynamics of connections amongst operators trading quotas A social network analysis approach was used to assess the factors influencing the operators' connectedness and in turn the effect of the connectedness on the market functionality.

ITQ systems have been clearly demonstrated to have success in reducing the so-called "race-to-fish" and have been effective in addressing problems of overcapitalization, shortened fishing seasons and low quality of product. Nonetheless, other issues and problems have emerged, in part because of spatial heterogeneity of resources, such as stock and congestion externalities. In the **Chapter 5**, an experimental economic approach was used to assess the potential for cooperative behaviour to reduce congestion externalities. This experiment was set in the context of management of a stock enhancement program as has been recently developed into a commercial operation in the TRLF (Gardner *et al.* 2015b).

Chapter 2

Do catch shares really promote resource stewardship?

2.1. Abstract

Theoretically, “catch shares” or individual transferable quotas systems (ITQ) are expected to provide economic benefits by improving efficiency through fleet rationalization and cost reduction as a consequence of removal of race to fish and stock rebuilding and higher catch rates when stocks were depleted. Resource stewardship in setting conservative total allowable catches (TACs) is thought to be rewarded through higher catch share values that result from security and more profitable harvests. This paper explores the TAC setting process in several ITQ managed coastal fisheries in Australia and New Zealand. It was examined whether TACs have been constrained to target higher profitability and thus increase asset values. Most of the analysed fisheries made decisions in line with expected behaviour under good stewardship, with this behaviour promoted by effective functioning of fishers’ associations. However, a non-trivial number of fisheries (26%) consistently showed lack of stewardship where the disagreement between government and industry remained, with industry continuing to lobby for TACs that dissipated rent. Several causes were identified with the most pervasive being a lack of understanding/acceptance of the rationale of ITQs systems with lower TACs equated with a reduction in profitability. The divergence between theory and reality in these fisheries shows that although stewardship in TAC setting is possible and even common, it cannot be entirely relied on ITQ systems and additional conditions are required to generate stewardship behaviour.

Key words: Catch share owners, economic and management assumptions, ITQ, rock lobster/abalone, stewardship

2.2. Introduction

Individual Transferable Quota (ITQ), or catch share systems, have been implemented in many fisheries around the world to constrain catch for biological objectives and in an attempt to create economic benefits through reduced competition for fish (Dupont *et al.* 2002; Fox *et al.* 2003; Costello *et al.* 2008). The transferable component of ITQ systems is intended to shift catch to more efficient operators through market forces driven by increasing the value of products and assets (Grafton *et al.* 2000; Dupont *et al.* 2005). Theoretically, these changes create a more stable, profitable and sustainable fishery.

Studies have shown that the risk of stock collapse is reduced with ITQ-based management (Costello *et al.* 2008, 2010) although this is related to the constraint of a total allowed catch (TAC) rather than the market-based attributes of ITQs (Bromley 2009). Several benefits arising from the tradeable aspect of ITQs have been proposed including the use of a market mechanism to promote efficiency through fleet rationalization (Dupont *et al.* 2005). Trading tends to result in a greater proportion of the catch being taken by more efficient operators, which raises the overall economic efficiency of the fleet. In the British Columbia halibut fishery, economic efficiency increased when the effort dropped as a result of a 28% reduction of vessel numbers(Grafton *et al.* 2000). Aside from vessel numbers, vessel characteristics (such as size) can respond to ITQs thus reducing costs and increasing efficiency (Bjørndal and Gordon 1993; Pascoe *et al.* 2011).

ITQs are also typically associated with relaxation of input controls such as the length of the fishing season, which increases the potential to 'fish to market' (Dupont *et al.* 2005). In the extreme case of the Alaskan halibut fishery, ITQ implementation led to an extension in the season from 24 hours to 200 days. The effect was an increase in landing price over of 40% due to the elimination of an over-supply at some times of the year (Casey *et al.* 1995) and because processors were able to supply fresh rather than frozen products (Bonzon *et al.* 2013). Increase in revenue can also be generated when intra-seasonal variations in fish characteristics or markets are taken into account in fishing programs (Larkin and Sylvia 2004). The relaxation of input controls (that may have been in place before the TAC and ITQs) can also directly affect capacity to fish and thus marginal costs of fishing. In the northern Gulf of Mexico reef fish fishery, an *ex ante* analysis estimated a 75% reduction in harvesting cost as a result of elimination of per trip catch limits, seasonal closures and transfer of catch shares to more efficient operators (Weninger and Waters 2003).

Although ITQs have been promoted on the basis of these gains in technical efficiency, there is also an argument for their use in relation to stock management where the constraint of the TAC results in increase in catch rate and thus reduction in cost (Breen *et al.* 2009). Formally, this process addresses the issue of the stock externality of fishing where harvesting reduces subsequent catch rates and thus increases the marginal cost of fishing. This means that constraint in catch provides an economic benefit. This economic benefit flows to quota holders and becomes capitalised where quota units or catch shares are allocated to individuals and traded in a market. Fishers are thus rewarded for decisions that increase future cash flows and this is theorised to create incentives to set conservative TACs (Gauvin *et al.* 1994; Brander and Burke 1995; Annala 1996; Breen and Kendrick 1997; Fujita *et al.* 1998; Grafton *et al.* 2006; Khan 2006; Wilen 2006; Yandle 2006b,a) , which is termed stewardship (Wilen 2006).

Resource stewardship by industry is clearly desirable because it reduces political conflict over catch setting by aligning sustainability and economic incentives. However, not all ITQ systems are equal and details of the system can affect the strength of the incentive for stewardship (Eggert and Ulmestrand 2008; Breen *et al.* 2009). The strength of systems that promote stewardship is thus of interest in terms of incentives for stock rebuilding and wealth creation (Hilborn *et al.* 2005)

The outcome of stewardship is thus central to the argument for implementation of ITQ systems. This research explored whether stewardship has been evident in several ITQ managed rock lobster and abalone fisheries in Australia and New Zealand. This question was addressed by exploring the TAC setting process, and whether decision-making has been consistent with the economic theory of ITQs. More specifically, whether TACs have been set in order to increase asset values, and whether governments and industry have been able to work cooperatively to set TACs that constrain current harvests to target higher profitability. In cases where decision-making did not appear to be consistent with stewardship, the reasons for this outcome were explored.

2.3. Methods

This research examined rock lobster (RL), green lip (GL) and black lip (BL) abalone fisheries in Australian and New Zealand. Australian fisheries in New South Wales (nsw, both RL/BL); South Australia northern zone (sanz, RL); southern zone (sasz, RL); central zone black lip stock (saczBL); central zone green lip stock (saczGL); southern zone fishing down area black lip stock (saszfdaBL); southern zone non-fishing down area black lip stock (sasznfdaBL); western zone-A black lip stock (sawzaBL); western zone-A green lip stock (sawzaGL); western zone-B black lip stock (sawzbBL) and western zone-B green lip stock (sawzbGL); Tasmania (tas, both BL/RL); Victoria central zone (viccz, BL); Victoria eastern zone (vicez, both RL/BL) and western zone (vicwz, both RL/BL). New Zealand fisheries in Crayfish stocks 1 to 9 (nzc1 to 9) and Paua (abalone) stocks 1 to 7 (nzp2 to 4, 5A, B, D, and 7). These fisheries were selected as they had the longest history of ITQ management in the region, were all simple single species fisheries, and are under different jurisdictions.

Stewardship and stock status history

Historical trends of stock status and asset values were used to check whether the expected stewardship from ITQ systems was translated into the TAC setting process. Data was obtained from stock assessment reports and from quota traders. To evaluate stewardship, fisheries were classified according their standardized changes in CPUE and TAC. Stewardship was assumed to occur when (*i*) the TAC was increased only when the CPUE increased, (*ii*) when the TAC was reduced in a response to a decrease in CPUE, and (*iii*) when the TAC was reduced when the CPUE remained constant and/or decreased (Fig. 2.1).

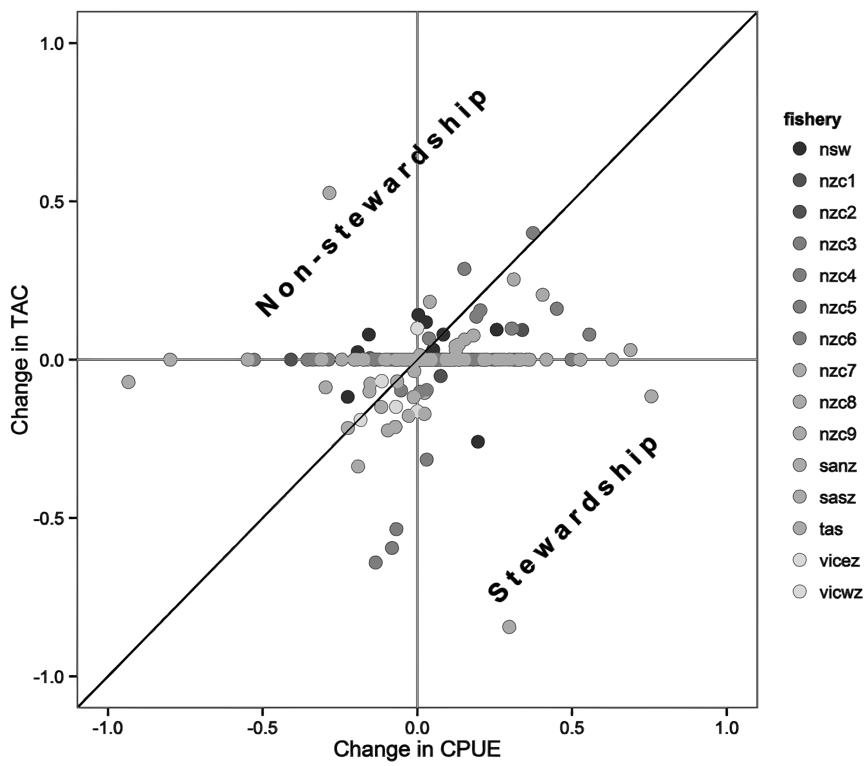

Figure 2.1. Changes in catch rates (CPUE) versus total allowable catch (TAC) used as criteria to classify different fisheries into stewardship or non-stewardship behaviour. Example based on Australian rock lobster fisheries in New South Wales (nsw); South Australia northern zone (sanz) and southern zone (sasz); Tasmania (tas), Victoria eastern zone (vicez) and western zone (vicwz); and New Zealand rock lobster fisheries in the management zone Crayfish 1 to 9 (nzc1 to 9).

Lack of stewardship was assumed to occur when (*i*) the TAC was increased, (*ii*) kept constant or (*iii*) only slightly reduced when CPUE proportionally dropped more than the TAC reduction applied (Fig. 2.1). A third category, labelled as *unclear*, was added to take into account small declines in CPUE without a reduction in TAC, as could occur with a decision rule approach incorporating target and limit reference points. Even with stewardship, a CPUE reduction may not be accompanied by a TAC reduction if the stock remains above a limit reference point. Consequently CPUE decreases of up to 30% without an accompanying TAC change were classified as *unclear*. In most fisheries TAC decisions are made for the next season using the previous season's data. Consequently a time-delay of two years was considered between CPUE changes and the corresponding TAC decision. A lag of two years to depict fishery behaviour according to CPUE changes was considered appropriate for generalising across fisheries because in most fisheries the TAC is set for the coming year during the current season using data from the previous season. Therefore, the previous year's CPUE is the closer reference.

CPUE changes were used to examine whether or not fisheries transitioned to or remained in the stewardship state with changes in the stock as measured by the CPUE. In the present research the CPUE values were standardized by the mean value of each fishery and the CPUE changes assessed were those that occurred after two years (*t-2*).

$$CPUE\ Change_i = CPUE_{i,t} - CPUE_{i,t-2}$$

Where $CPUE_{i,t}$ is the catch rate of the fishery i at the present and $CPUE_{i,t-2}$ is the catch rate of the same fishery two years ago. Positive values of *CPUE Change* implied that the catch rate increased and vice versa.

Stewardship state changes

Transitions between the behavioural states of stewardship and non-stewardship were analysed using Multistate Markov (MSM) models (Kalbfleisch and Lawless 1985; Jackson *et al.* 2003). The likelihood of this model was calculated from the transition probability matrix $P(u, t+u)$. Every element $p_{r,s}(u, t+u)$ of the matrix corresponded to the probability of being in the state s at time $t+u$ given the state r at time$u$. The transition probability matrix was obtained using maximum likelihood estimation through the R package *msm* (Jackson 2011). $CPUE\ Change$ was used as a covariate, and values of transition rates between states were plotted against this covariate.

TAC setting process

The degree of agreement on TAC setting between industry and the fisheries management authority was assessed by survey, with 81 researchers, fisheries managers and fishers invited to participate. The survey included questions exploring the occurrence of disagreement when a reduction of the TAC was required and any associated factors. The purpose of this survey was to put into context previously identified factors and avoid to discuss any speculative one and unlikely to happen in ITQ managed fisheries. Some factors were gauged by more than one question. For instance, the factor *Not understanding the ITQ system* was assessed by the questions that focussed on how quota owners understand TAC reductions and the effect of higher catch rates on costs. The survey also focussed on situations where the industry had asked for a reduction in the TAC. The survey included Likert-type questions with the following ordinal scale (Rainer *et al*. 2007): *not important*, *minor effect*, *important*, *very important* and *most critical factor* (Appendix 2.1). To summarize the answers and simplify analysis, the five ordinal scale levels were transformed to a binary scale. Thus, *not important* and *minor effects* were merged into the *not important,* and *important*, *very important* and *most critical factor* were merged into the category of *important*. The proportion of respondents that considered the factors involved in the TAC setting process important or not is presented in the summary. The importance of factors associated with industry negotiations for a TAC reduction was also determined using the binary proportion of responses. .

2.4. Results

Stewardship and stock status history

The trends of occurrence of stewardship based on trends in CPUE and TAC revealed two patterns, (*i*) a consistent occurrence of stewardship, and (*ii*) one where behaviour varied between stewardship and non-stewardship (Fig. 2.2).

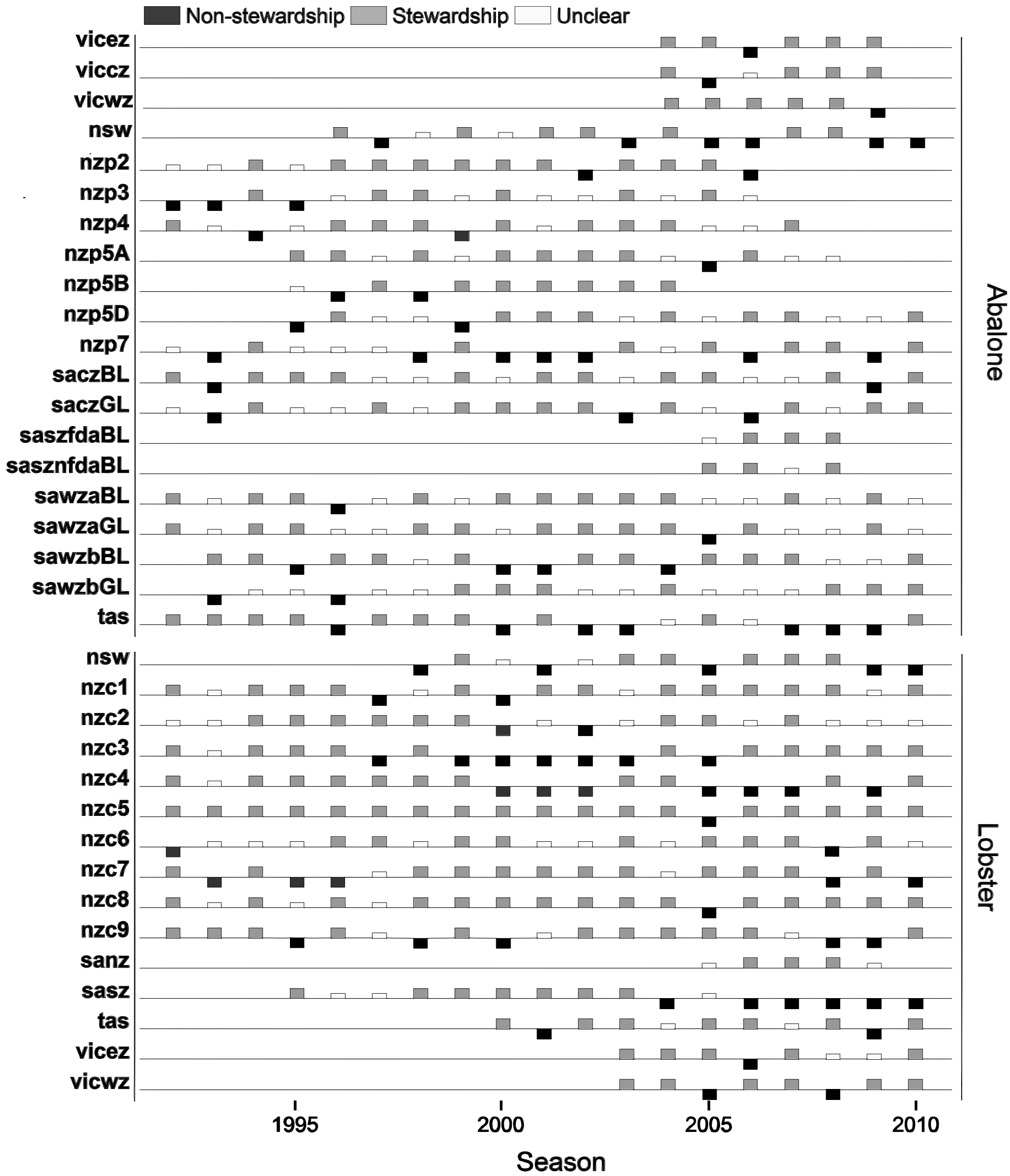

Figure 2.2. Historical trends of occurrence of stewardship / non-stewardship in Australian and New Zealand rock lobster (RL), green lip (GL) and black lip (BL) abalone fisheries. Australian fisheries in New South Wales (nsw, both RL/BL); South Australia northern zone (sanz, RL); southern zone (sasz, RL); central zone black lip stock (saczBL); central zone green lip stock (saczGL); southern zone fishing down area black lip stock (saszfdaBL); southern zone non-fishing down area black lip stock (sasznfdaBL); western zone-A black lip stock (sawzaBL); western zone-A green lip stock (sawzaGL); western zone-B black lip stock (sawzbBL) and western zone-B green lip stock (sawzbGL); Tasmania (tas, both BL/RL); Victoria central zone (viccz, BL); Victoria eastern zone (vicez, both RL/BL) and western zone (vicwz, both RL/BL). New Zealand fisheries in Crayfish stocks 1 to 9 (nzc1 to 9) and Paua (abalone) stocks 1 to 7 (nzp2 to 4, 5A, B, D, and 7).

Most fisheries that had a consistent pattern of occurrence of stewardship reduced the TAC and/or kept it constant even when the CPUE increased. For instance, in the rock lobster fishery nzc9 in New Zealand the TAC was reduced in 1991 and kept constant at a low level even after a rise in CPUE in 2003 (Fig. 2.3a and b). Stewardship was observed in nzc9 throughout the analysed period (Fig. 2.2). Similarly consistent stewardship behaviour was evident in the rock lobster fisheries nzc1, nzc5 and nzc6 (Fig. 2.3a and b); and by abalone fisheries in New Zealand nzp3 to nzp5 and South Australia, sawzaBL, saczBL and saczGL (Fig. 2.4a and b). In all these fisheries the TAC was not increased even when the CPUE rose.

The pattern of irregular stewardship was a result of a number of different TAC decisions. In some fisheries, a reduction in the TAC was applied too slowly after decline in CPUE. For instance, in the rock lobster fishery nzc3, the CPUE trended down from 1998 to 2004, but the TAC was kept constant until 2005 when the TAC was reduced by 58% (Fig. 2.3a and b). A similar situation occurred in other fisheries; however, in these fisheries the TAC was more gradually reduced; but this also meant that stock rebuilding after a decline took longer. For example, in the South Australian rock lobster fishery (sasz) the TAC was kept constant for four years despite a decreasing pattern in CPUE. After this the TAC was gradually reduced by 6.8%, 19.5% and 7.9% until reaching a TAC level that allowed the stock to rebuild.

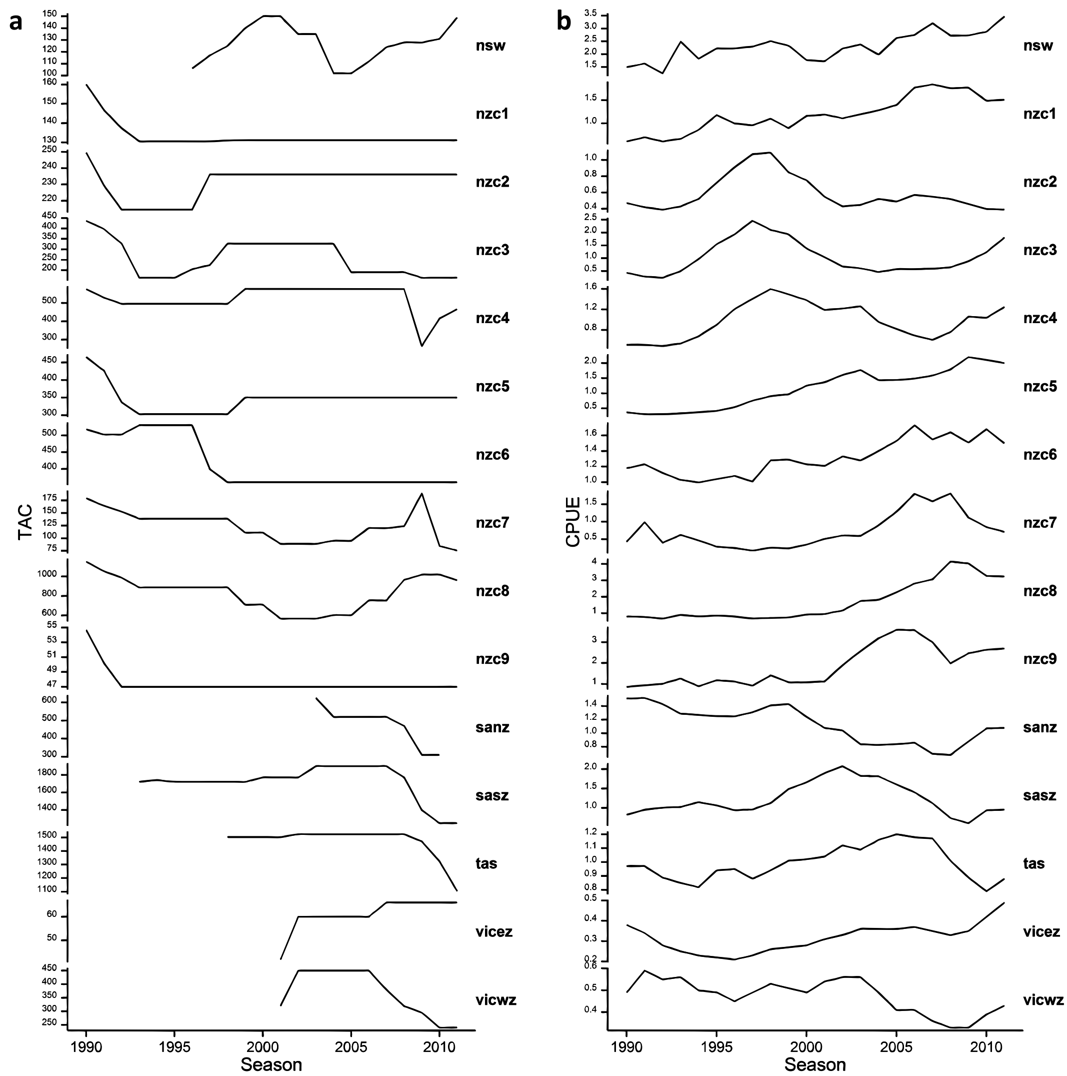

Figure 2.3. Stocks status indicators of rock lobster fisheries in Australia and New Zealand. Australian fisheries in New South Wales (nsw); South Australia northern zone (sanz); southern zone (sasz); Tasmania (tas); Victoria eastern zone (vicez); western zone (vicwz) and New Zealand fisheries in Crayfish stocks 1 to 9 (nzc1 to 9). CPUE: Catch per unit of effort, TAC: Total allowable catch.

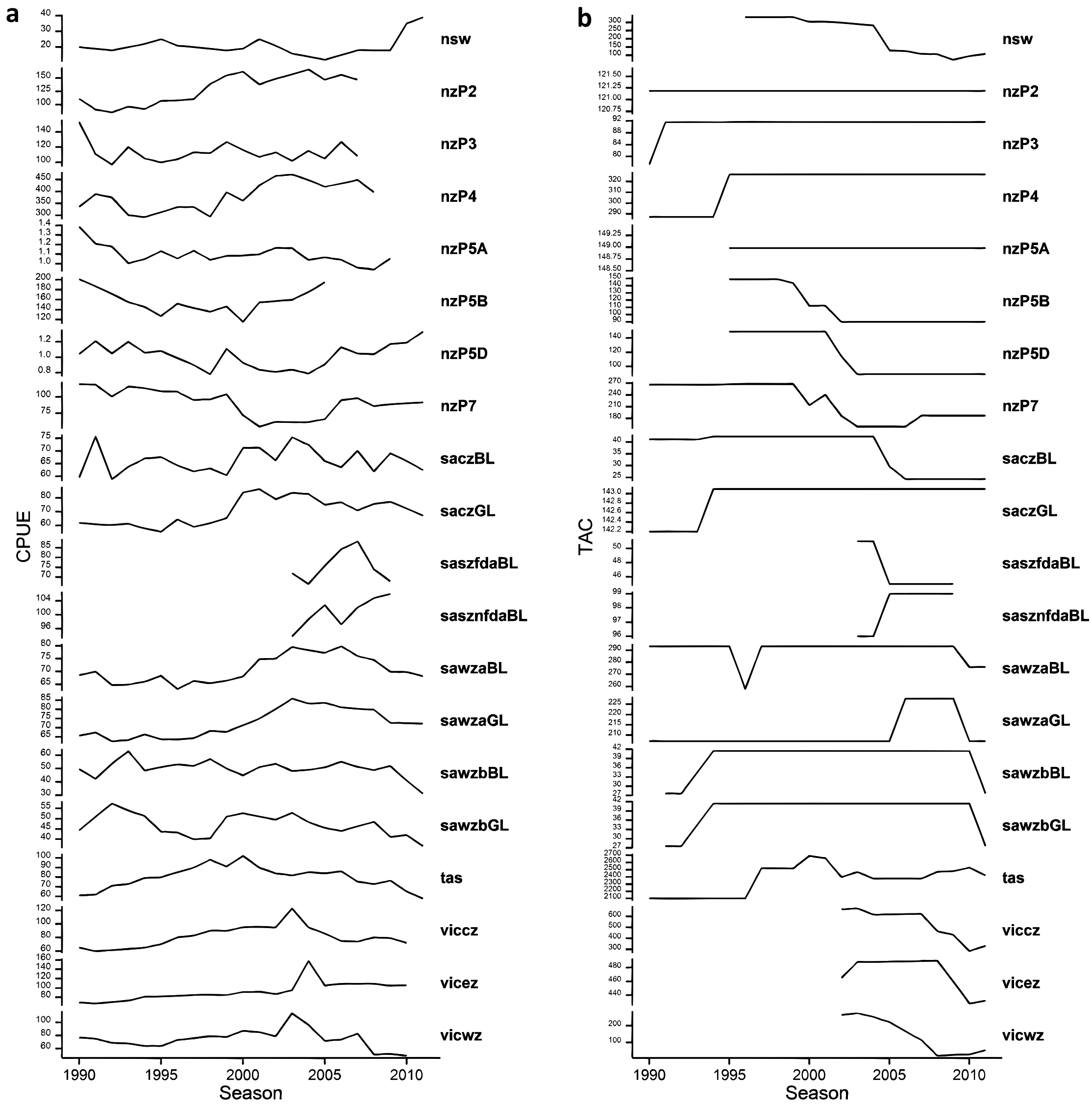

Figure 2.4. Stocks status indicators of abalone fisheries in Australia and New Zealand. Australian fisheries in New South Wales (nsw); South Australia central zone black lip stock (saczBL); central zone green lip stock (saczGL); southern zone fishing down area black lip stock (saszfdaBL); southern zone non-fishing down area black lip stock (sasznfdaBL); western zone-A black lip stock (sawzaBL); western zone-A green lip stock (sawzaGL); western zone-B black lip stock (sawzbBL) and western zone-B green lip stock (sawzbGL); Tasmania (tas); Victoria central zone (viccz); Victoria eastern zone (vicez) western zone (vicwz) and New Zealand fisheries in Paua (abalone) stocks 1 to 7 (nzp2 to 4, 5A, B, D, and 7). CPUE: Catch per unit of effort, TAC: Total allowable catch.

Irregular patterns in stewardship were also observed in some fisheries where the TAC was immediately increased as soon as the CPUE began to increase following a period of TAC reduction. For instance, in the rock lobster fishery in NSW between 2001 and 2004, the TAC was reduced, enabling rebuilding of the stock. However, from 2006 the TAC was increased again, which by 2009 resulted in the proportional increase of the TAC being higher than the increase of CPUE from stock rebuilding. The TAC was then brought back to the original level that drove CPUE down (Fig. 2.3a and b). A similar series of decisions occurred in the New Zealand rock lobster fisheries nzc3 and nzc4.

Stewardship state changes

In general, stewardship was most likely to happen when CPUE showed positive changes. The number of incidences of transition from the non-stewardship state to the stewardship state increased when stocks rebuilt and CPUE changes went from negative to positive (Fig. 2.4). Conversely, fisheries were more likely to remain in the non-stewardship state when stocks were in a declining condition (negative CPUE differences). The probability of remaining in a non-stewardship state decreased when stocks showed increased CPUE values. After reaching a stewardship state in both abalone and rock lobster fisheries, the probability of transit to a non-stewardship state was less than 30%, even with high CPUE reductions. In comparison, abalone and rock lobster fisheries were highly likely (>60%) to remain in a stewardship condition, even with decreasing CPUE changes. Comparing abalone and rock lobster fisheries in non-stewardship condition, rock lobster fisheries required higher levels of stock rebuilding to transit to a stewardship condition.

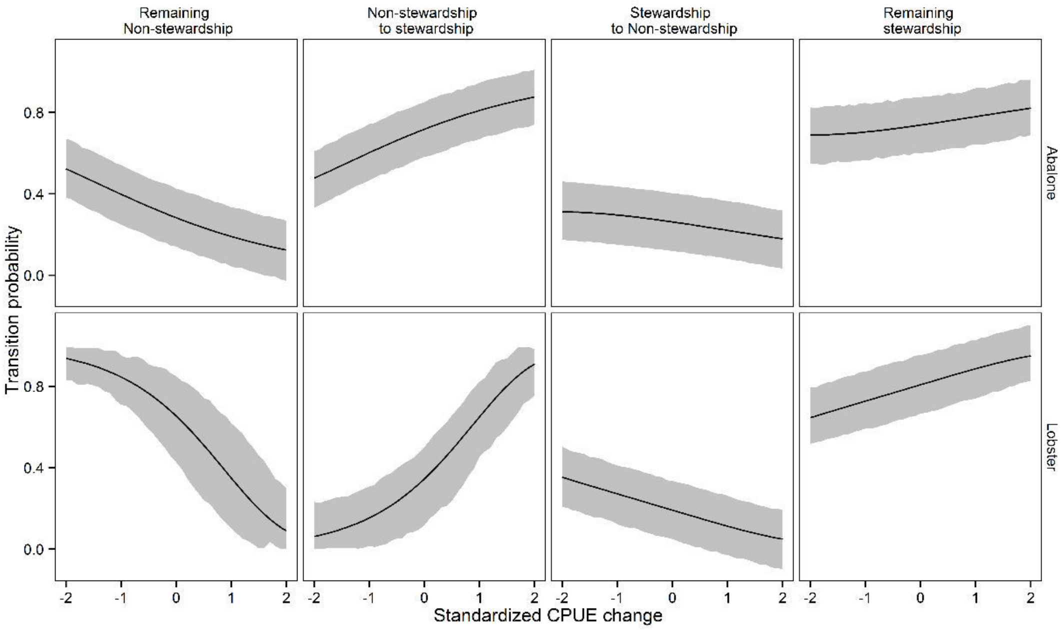

Figure 2.5. Probability of fisheries transiting between the states occurrence and non-stewardship versus changes in CPUE values. Positive values of standardized CPUE change imply an increase of the catch rate and vice versa.

TAC setting process

A total of 60 (74%) of the people invited to participate in the survey completed the questionnaire, 42% were fisheries managers, 33% researchers, and 25% fishers and quota owners. A total of 23 fisheries were covered (Appendix 2.2). The first part of the questionnaire focused on the factors that may explain disagreement between industry and government (including research). This part of the survey was fully completed by 49 (82%) respondents. The second part focused on factors that explain the drivers behind industry calls for a TAC reduction. As not all fisheries had experienced a TAC reduction, this second section was completed by 31 (52%) respondents.

Survey respondents had varying opinions on consensus on TAC levels between industry and government with: 32% of respondents stating that the TAC supported by the industry was higher or much higher than the TAC supported by the government, 39% of respondents thought that both positions were similar, and 29% of respondents stated that the industry proposed a lower TAC than the government. In situations where the TAC was lowered, 44% of respondents believed that 50% or more of the members of the industry had resisted the TAC reduction.

Resistance to lowering the TAC was indicative of a lack of stewardship and numerous different factors were proposed as contributing to this. The most important factors identified by respondents for explaining industry and government disagreement were: (*i*) not understanding ITQ systems (Q8 and Q9); (*ii*) concern about immediate cash flows (Q16); (*iii*) concern about uncertainty in future performance of the fishery (Q15); (*iv*) not getting benefit from an increase in catch share value (Q14 and Q13); (*v*) no interest in benefit from an increased quota value (Q17 and Q12); (*vi*) fishing efficiency heterogeneity across the fleet (Q20); and (*vii*) concern about shifting resources to other sectors (Q18). *Not understanding the ITQ systems* was a factor considered highly important by respondents. Hence, 90% of respondents believed industry viewed lower TACs as inevitably leading to a reduction in profit (Q8) and

62% of respondent believed that quota owners did not consider the effect of higher catch rates on cost of fishing (Q9) (Table 2.1).

Table 2.1. The relative importance of factors that may explain disagreement between the industry and the government's position on TAC setting.

Factor	Question	Proportion of survey respondents (%)	n
Not understanding ITQ systems	Q8	90.24	41
	Q9	62.16	37
Concern about immediate cash flows	Q16	77.5	36
Concern about future fisheries performance	Q15	71.79	38
Not getting benefits from catch share value	Q14	56.41	40
	Q13	30.77	39
Partially or not interested in the catch share values	Q17	46.15	39
	Q12	37.50	39
Fishing efficiency heterogeneity across fleet	Q20	50.00	40
Lower TACs would transfer resources to other sector	Q18	42.50	39
Catch shares can be quickly traded	Q10	19.44	40
Investor-catch share owners detached from the fishery	Q11	18.42	39
Future prices would be lower	Q19	15.38	38

Questions related to the factor *concern with immediate cash flow* were rated as important by 78% of respondents. For 72% of respondents there was *concern about future fisheries performance* with uncertainty associated with the scale and timing of cost reduction that would occur with stock rebuilding. The factor *not getting benefits from catch share value* captured the fact that fishers who did not own catch shares were more concerned with reduction in employment than the value of catch shares, and 56% of respondents considered this factor important.

Close to 50% of the respondents regarded the factor that some quota owners may be *partially* or *not interested in the quota values* as important, as they may have some other interest in the fishery. For instance, for active fishers, the pride and enjoyment of catching fish may provide additional utility to business profit, and this was considered important by 46 % of respondents (Q17). Similarly, some quota owners combined fishing with processing and they receive benefit from greater catch volumes in addition to the value of their catch share. This factor was considered important in explaining non-stewardship behaviour by more than one third (38%) of the respondents (Q12).

The *heterogeneity of fishing efficiency* describes the difference in cost structures between different fishers. A change in the TAC that may benefit the 'average' operator does not benefit all operators. This is potentially a source of disagreement amongst fishers in supporting conservative TACs and was considered important by 50% of respondents. Forty three per cent of respondents considered the fishers' concern about *lower TACs would transfer resources to other sectors as* important. For example, lower TACs would result in higher catch by the recreational sector rather than increase in stock.

Three factors were considered unimportant by more than 80% of respondents. First, the factor of *catch shares can be quickly traded*, which describes the situation where quota owners press for higher TACs to get the short-term benefit of higher revenue and then sell their catch shares before the value is affected by falling catch rates and thus higher cost (Q10). Second, *they would be detached from the fishery* which describes the situation where investor-catch share owners, and have a poor understanding of the fishery and thus do not understand the implications of TAC decisions (Q11), and third, catch share owners' concern that *future prices would be lower* than current prices; therefore, reducing the incentive to save stocks for the future (Q19).

Survey respondents had the opportunity to provide commentary on factors led to disagreement between industry and Government. The most frequently mentioned factor was that some industry members did not understand the rationale underlying ITQ systems, which was also evident in the strong response to *Not understanding the ITQ systems* (Q8 and Q9). Several examples of this misunderstanding of ITQ systems were provided. For instance, some catch share owners were concerned about TAC reductions because they believed that if the TAC was reduced it could never return to the original level even if stocks recovered. Another way the ITQ system was misinterpreted was the perception that TAC reductions inevitably led to reduction in the value of catch shares. The corollary point was also made where fishers argued for higher TACs in the belief that this would inevitably increase the value of catch shares, with no regard of changes in catch rate, and thus cost of fishing, or longer term production. Additionally, survey respondents mentioned the potentially conflicting interests of catch share owners within in the fishery, such as where processing companies who own catch shares were more driven by the benefits of greater volume of product passing through their factory. Sometimes quota owned by these facilities has most value in leveraging catch and thus market share through complicated deals with other quota owners.

An additional factor mentioned by respondents was mistrust of government and scientists by industry members but also mistrust between industry members themselves. Lack of trust among industry members was reflected in formation of factions within the industry with different interests, and a mistrust of industry leaders. Industry members did not trust government because they thought that fisheries managers did not have the required skills and that the decisions made by the government may have implicit political interests or bias.

Survey respondents believed that *Experience and knowledge* was most important for explaining why some industry members asked for lower TACs, that is, provided clear evidence of stewardship (Table 2.2). There were four aspects which survey respondents considered important: the presence of an industry leader to explain and drive decisions (Q25), a functional industry group who could work together in forming consensus (Q27), industry members who understood the rationale of the ITQ systems and the way stock abundance affected the value of their catch shares (Q29); and observations or exposure to good outcomes from keeping the TAC low in other fisheries (Q28). The presence of *few interactions with other sectors* (MPAs and recreational) was considered an important factor contributing to stewardship by 39%

of the respondents (Q26). Less important factors for promoting stewardship were whether industry member were willing to consider information from economic analyses including bioeconomic modelling (Q24) and market aspects of the fishery (Q30 and Q31).

Table 2.2. The relative importance of factors that may explain demands for lower TACs related to stewardship (n= 31).

Factor	Question	Proportion of survey respondents (%)
Experience and knowledge	Q25	83.87
	Q27	80.65
	Q29	74.19
	Q28	48.39
Few interactions with other sectors	Q26	38.71
Information from economic analysis - bioeconomic modelling	Q24	29.03
Market aspects	Q30	19.35
	Q31	9.68

2.5. Discussion

The allocation of catch shares to fishers in ITQ systems theoretically produces a series of positive stock externalities that promotes stewardship of the resource (Wilen 2006; Costello *et al.* 2008, 2010). This occurs through a process where catches are constrained so that catch rates increase, reducing the cost of fishing, which then increases profitability. If the catch shares are traded in an ITQ system, their increased profitability is reflected in an increase in capital value. This theoretically provides an incentive to limit catches to gain higher profits in the future, thus leading to resource stewardship. The results of this study reveal that a large proportion of the analysed fisheries have responded as expected, making TAC decisions in line with resource stewardship. However, a non-trivial proportion (26%) of fisheries showed variable behaviour with TAC decisions that alternated between a state of stewardship and non-stewardship as defined in this study by TAC response to CPUE. This raises the question of why TAC reductions have been resisted in some cases and can ITQ systems be relied upon for creating stewardship?

Firstly, it is notable that ITQ systems are not necessarily required for stewardship to exist or to encourage constraint in catches. Stewardship has been reported in the absence of individual catch shares (Berkes *et al.* 1989; Agrawal 2001); or when catch shares were in place but non-catch-share owners were more conservative at setting TACs than catch-share owners (Gilmour *et al.* 2012). It was observed this in the current study with abalone divers in some fisheries, who did not own catch shares, but were reportedly more supportive of conservative TACs than many owners of the catch shares. This was because the divers had greater financial exposure to changes in stock abundance and thus catch rate. It was concluded that catch share allocation *per se* is neither a prerequisite nor sufficient to promote stewardship and additional conditions are required.

The results of this study suggest that a high level of cooperation and leadership in fisher organisations is an important part of the requirements for stewardship to exist –

but there may still be a need for additional factors. One factor that assists stewardship is experiencing the positive feedback from increased profits that can occur as a result of a constraining TAC and stock rebuilding. Fishers may need to see outcomes of stock rebuilding in practice before they support it. One of the respondents described initial industry resistance to a TAC reduction of about 50%. However, after ten years of experience the effect of higher stocks on profits, this respondent supported keeping the TAC at a reduced level. In the fisheries examined here, once stewardship had occurred, the fishery was more likely to remain in a state of stewardship. Exposure to economic benefits from a management policy is a factor that positively influences the fishers support for fisheries policies (Allegretti *et al.* 2012). An implication of this is that providing fishers with control of TACs through co-management may not result in good stock outcomes unless fishers have already experienced the effects of stock rebuilding.

In some of the fisheries stewardship behaviour was inconsistent through time. In these fisheries there was disagreement between industry and government on the required changes to the TAC, mostly by industry opposition to limiting the TAC. A number of factors that contributed to this lack of stewardship were identified, which are discussed below.

Quotas were viewed as a tool to protect stocks rather as an economic instrument

The market values of catch shares are not simply determined by current profits, but also perceptions of future cash flows. These future cash flows are linked to the interplay between higher revenue from higher TACs and lower costs from lower TACs. Viewed in this way the TAC is an economic instrument with an optimal level that maximises cash flows. However, the TAC also serves a more basic purpose, which is to constrain catch to prevent recruitment overfishing. In some fisheries the role of ITQs as an economic instrument was not widely understood and they were simply considered to be a management control to ensure sustainability. Therefore, as soon as stocks rebuilt the TAC was seen to have served its purpose and fishers lobbied for a TAC increase (e.g. in the rock lobster and abalone fisheries in Tasmania and New South Wales).

TAC decisions were viewed in terms of revenue rather than profit

Some fisheries tended to be more concerned with the effect of the TAC on revenue (i.e. catch × price) rather than profit (i.e. revenue − costs). The following survey respondent's statement illustrates this point, "I fish to the market, not to maximise my CPUE". Respondents noted that in the Tasmanian rock lobster fishery increases in the TAC were typically viewed as good for fishing businesses because revenue increased, regardless of the effect on the cost of fishing (because of reduced catch rates) and thus profit. Another example of this issue is where catch share owners claimed that lower

TACs harm future profits in their efforts petitioning the government for reduced fees for management and other services (Ward 2011). This reveals dissociation between lower TACs and potentially higher profits.

The factor that contributes to this disassociation indicated by respondents was that quota owners could easily estimate changes in revenue, but changes in fishing costs were uncertain and difficult to quantify. Changes in catch rate and associated changes in costs were the result of interactions between the fish stock and the entire fleet, whereas changes in revenue were directly apparent to the individual operator through their catches. Respondents also said that change in revenue is immediate, whereas change in fishing costs may only be seen over the long term.

The sanz rock lobster fishery provided an example of how the TAC decisions were based on revenues rather than profits. In this fishery the catch rates fell for several years and the TAC was not constraining. There was industry resistance to lower TACs and instead catch share owners proposed government buy-back of effort (Econsearch 2010a; Linnane *et al.* 2010c). This history was not consistent with stewardship and appeared to be caused in part by associating profitable business with large catches and revenues. The desire of some individuals in the sanz rock lobster fishery to maintain higher TACs while also arguing for interventions to reduce the number of vessels suggests that the outcome of the ITQ system was not well understood. The absence of a constraining TAC has been shown to increase the number of operators because lease quota becomes available at a low price, which then provides an incentive for new entrants to the fishery (Emery *et al.* 2014a).

There was uncertainty around stock rebuilding outcomes

Expectations around stock rebuilding and the scale of change in catch rate are critical to any decision to constrain the catch. The opportunity to observe stock rebuilding in similar fisheries can be helpful, as occurred with NZ fishers in the management area CRA 4 who saw large increases in rock lobster stocks in a similar fishery at CRA 8 when the TAC was reduced in that zone (Breen *et al.* 2008). This understanding of stock rebuilding and resultant stewardship led fishers to voluntarily establish a performance rule to constrain the TAC (Breen *et al.* 2009; Miller and Breen 2010). This factor is related to the observation from other fisheries that a lack of stewardship occurred where there was lack of understanding of stock rebuilding.

The industry is not a simple collective of catch share owners

Some specific groups of stakeholders, such as fishing labourers or processors, receive most benefit when the tonnage of the catch rather than the economic yield is maximised. These stakeholders were sometimes included in the consultation or industry group processes used to develop a consensus position on future TACs. Survey respondents said that in these situations the industry tended to favour higher TACs and exhibit less stewardship. In contrast, decision-making that involved greater representation of catch share owners may be more focused on long term asset prices than tonnage. This was the case in New Zealand rock lobster stocks where the advisory committee was mainly made up of catch share owners-operators (e.g. nzc8) who were closely involved in the management decision process (Yandle 2008a).

Voting systems can skew the position of industry representative groups resulting in either more or less stewardship in quota setting. In some fisheries such as the NZ stocks or the Tasmanian abalone fishery, the voting process schema was proportionally based on quota ownership, basically one vote for each catch share (Yandle 2008b). Survey respondents explained that in the Tasmanian rock lobster the voting system was based on one vote for each member, and membership included processors, deckhands, lease fishers, and catch share-owners. These different structures were considered to affect the outcome of the overall vote thus affecting the overall degree of stewardship in TAC setting.

Fishers may have a high discount rate

Stewardship in setting low TACs to rebuild stock involves foregoing current earnings to increase long-run profitability. The willingness of operators to take this step is a function of their discount rate, how much more they value current earnings compared to those in the future. Fishing is a risky business because of stock uncertainty driven by factors such as recruitment failures and diseases. Uncertainty favours high discount rates (Piourde and Bodell 1984), creating greater emphasis on the present value, which would be expected to result in support for higher TACs.

There are also business and market factors that can affect discount rate (Midani and Lee 2014) and thus stewardship. Survey respondents said that catch share owners tend to lobby for higher TACs when they have greater levels of borrowing or are otherwise more exposed to short-term cash flow issues in their business. A less frequent occurrence was where catch share owners had high discount rates when they wanted to exit the fishery. For instance, in the viccz abalone fishery, industry members were able to reach consensus prior to the outbreak of a disease that devastated the stock (Abalone Viral Ganglioneuritis). However, after this disease outbreak the group split into two factions, with one wanting to sell their quotas and lobbying for higher TACs to maintain the quota price despite large decline in stock abundance.

Fisher's non-financial utility from fishing

Stewardship theoretically arises with ITQs because long-run earnings and wealth of catch share owners increases. However, some respondents believed that there are non-monetary benefits of fishing that also influence decision making but are not captured. Their point was that some fishers consider fishing an intrinsically enjoyable activity and prefer to maintain the capacity to take larger catches. Challenges such as finding fish, developing skills to work in a risky environment, competition with others fishers and being an independent business person amongst other factors, contribute to job satisfaction (Gatewood and McCay 1990; Pollnac *et al.* 2001; Pollnac and Poggie 2006). This seems particularly the case for fishers who have a family history of fishing and who operate in remote areas. These fishers attribute additional non-monetary value to fishing, which is not only based on enjoyment of fishing but also on apparent barriers to moving to another type of employment (Smith 1981). Thus long term gains in catch rates from lower TACs may not outweigh the total loss of utility from lower catches. As a fisheries manager who answered the survey mentioned, “many fishers say that quota systems stop them from being 'fishermen'”.

There is less benefit from a lower commercial catch if allocation is shifted to other sectors (recreational, MPAs)

The benefits of constraining TACs occur through stock rebuilding and subsequent increases in catch rates. However, this benefit is reduced if the catches or stocks are shifted to another sector. While ITQ systems grant exclusive fishing allocations to the total allowable commercial catch, it is possible for recreational catch or coverage of MPAs to expand independently thus negating any benefits of constraint in catch.

Recreational catch may reduce stewardship of catch share owners through a simple process where a lower commercial TAC results in higher recreational catch rates, leading to increased recreational participation and slowing of stock rebuilding. Additionally, the unknown amount of fish caught by the recreational sector introduces uncertainty in the system (Yandle 2008a), which affects the catch share owners' willingness to be stewards, as the confidence in the management system is weakened. This effect was mentioned by survey respondents, and they also said that the effect of this on stewardship was greater when the recreational catch was large and was given preferential allocation.

Declaration of MPAs can also reduce stewardship by catch share owners because they displace catch into the resultantly smaller areas that remain open for fishing. This reduces or even eliminates any benefit to catch share owners from TAC reduction in terms of increase in catch rate (Hobday *et al.* 2005; Hilborn *et al.* 2006). Fishers are conscious of this potential impact of MPAs and have said they undermine ITQ systems, in particular the value of fishing allocations (Treloggen 2005). The short-term effect of MPAs immediately impacts individual operators that are directly displaced, but in the long term all operators are impacted if catch is displaced to fishing grounds reduced in size. Fishers will experience higher costs as they need to develop expertise in fishing in new grounds (Econsearch 2010a,b).

The effects of recreational fishing and MPAs on stewardship of catch share owners in TAC setting occur because they affect the security of the allocation. This security is considered critical to operators in terms of profit maximization and long-term stewardship (Grafton *et al.* 2000; Arnason 2007) and is also reflected in the market price of quotas (Arnason 1990; Batstone and Sharp 2003).

2.6. Conclusion

Resource stewardship behaviour that is theoretically associated with ITQ systems is likely to occur where catch share owners are focused on long-run maximization of economic yield. Patterns in TAC setting and catch rates in most rock lobster and abalone fisheries in Australia and New Zealand examined here were consistent with this theoretical outcome of ITQ systems. Stewardship tends to be present in fisheries with well-developed and functioning fisher associations led by individuals who were able to drive stewardship decisions and consensus. However, variable stewardship behaviour through time was also observed in a considerable number of fisheries. In these cases, industry did not always lobby for or support TACs that would result in stock recovery and long term increase in economic yield.

There were many factors that contributed to the lack of stewardship in these ITQ fisheries. The most important appeared to be a lack of understanding of the principles and purpose of ITQ systems by catch share owners. They saw TACs as a sustainability control mechanism and not as an economic instrument; therefore, they lobbied for a TAC increase as soon as stocks began to rebuild. The relationship between abundant stocks and lower costs associated with lower TACs was poorly understood, sometimes driven by the fact that they had no historical experience of stock rebuilding. Often catch share owners were more focused on revenues than profit and were more concerned about the loss of revenue from lower TACs than cost reduction from higher catch rates. Some catch share owners have high discount rate, such as when exposed to immediate cash-flow issues or when planning to exit the fishery in the short term. A lack of stewardship could also occur as a result of the voting systems used to develop the industry position on TACs, such as where the vote did not reflect the interests of catch share owners. Other issues that were less important but still undermined stewardship included the presence of non-financial benefits some fishers get from taking large catch, and competition for allocation of the stock with other sectors, such as recreational fishers and MPAs.

This article provides evidence that the implementation of ITQs does not automatically result in resource stewardship by industry and additional conditions and management are needed to achieve industry wide stewardship. In the absence of these additional conditions, catch share owners are likely to continue to display the behaviour that ITQ systems were meant to eliminate and the arm wrestle between industry and Government in setting TAC levels will remain. This is especially critical when co-management schemes provide greater industry control in TAC setting. Part of implementing effective ITQ systems thus involves resourcing effective training and communication to the industry on the functioning of ITQs as an economic instrument. There is also a need to recognise that industry cannot be expected to exhibit stewardship in TAC setting in some fisheries; for example, if the industry association is dominated by firms that do not own ITQ units and benefit from large volume of product (e.g. lease fishers and processors) or where there is significant competition with other sectors (e.g. recreational fishers and MPAs). Careful planning of the inherent details of ITQ systems is required if existing resource stewardship is to be maintained and stewardship is to be initiated where it is currently absent.

2.7. Appendices

2.7.1. Appendix 2.1: Survey applied to quota owners fishers, fisheries managers, and researchers to assess the conditions needed for resource stewardship to occur in ITQ systems.

Survey applied to quota owners fishers, fisheries managers, and researchers to assess the conditions needed for resource stewardship to occur in ITQ systems.

Survey: Total allowable catch setting in fisheries managed under individual transferable quota system

Respondents choose between the following alternatives, unless other options indicated:

not important / minor effect / important / very important / most critical factor

For every question there was a textbox for optional comments.

I. Respondent profile

1. Position

2. Fishery

3. Do you engage in the TAC setting process for a fishery?

4. Fishery: please give jurisdiction and species

II Industry participation

5. Has there been industry involvement in the year-to-year TAC setting process since ITQs were implemented, such as in committee discussions?

Yes/No, There is a decision rule instead TAC committee discussion (If so, please, complete the rest of this survey thinking about the situation before the decision rule)

III Goverment-industry dis/agreement on TAC setting

6. Thinking about TAC decision in the last 10 years, how different from the Government's position were the TACs supported by the industry?

7. Thinking of the most significant case when the TAC was lowered, roughly what proportion of the industry resisted this change?

almost all / about 75% / about 50% / about 25% / none / N/A (the TAC has never been reduced) / Other (please specify)

IV Why did some (or all) industry members resist a lower TAC?

We're interested in knowing the details behind situations when industry resists having lower TACs. Do you think that any of the following factors played a part? (There can be more than one factor involved)

There was resistance to reducing the TAC because: ...

8. Lower TACs were viewed by the industry as inevitably leading to a reduction in profit.

9. Industry didn't consider the effect of higher catch rates on lower costs.

10. Quota owners can trade in and out of the fishery quickly so can get the short term benefit of higher catches....and then sell out before catch rates decline.

11. Quota owners were detached from the fishery (investors) and had a poor understanding of the fishery so failed to appreciate the benefit of higher catch rates

/ lower costs that tend to occur with lower TACs.

12. Quota owners had some other interest in the fishery, which benefited from volume of product. For example, if quota owners were also processors they could benefit from higher volumes of product into their processing operation.

13. Fishers who didn't own quota had little financial exposure to the value of quota units.

14. Fishers who didn't own quota were concerned that a lower TAC would lead to fewer vessels and / or reduced employment.

15. Active fishers were concerned about uncertainty in the scale and timing of cost reductions that would occur with stock rebuilding.

16. Active fishers were concerned with immediate cash flow rather than long-term improvement in profitability (e.g. if their cash flow was squeezed because of loans and the need to maintain payments).

17. Beside considering business profit he pride and enjoyment of catching fish may be important for active fishers. How important was that?

18. Industry members were concerned that a reduced commercial catch would shift the resource to other sectors; for example, by helping expansion of recreational catch or MPAs.

19. Quota owners were concerned that future quota prices may be lower than current prices, so there was little point in saving stock for the future.

20. The fishery was a mix of individuals. Some were better fishers who have higher catch rates even when stocks are reduced. For these individuals, arguing against lower TACs was rational for their profitability.

21. Were there any other factors that led to some industry members arguing against a lower TAC?

V Industry resisting higher TACs

22. Has there been a situation in your fishery where industry members asked for a TAC reduction?

Yes / no

23. Has there been a situation in your fishery where industry members asked to keep TAC constant?

Yes / no

VI Industry resisting higher TACs

When some (or all) industry members called for lower TACs or resisted higher TACs, were any of the following factors important?

24. Information from economic analyses or bioeconomic modelling.

25. An industry leader who helped explains and drives the decision.

26. Few interactions with other sectors such as recreational fishers or MPAs provided fishers with confidence that they would directly benefit from higher stock abundance.

27. The industry group worked well together in forming consensus.

28. Industry members were motivated by observations of good outcomes from keeping the TAC low elsewhere (even in a different fishery).

29. Quota owners were concerned about the value of their quota units and wanted to increase or protect the value of these units.

30. Industry was looking for access to certain markets, which was difficult without higher stock abundances at certain times.

31. Certification schemes or some other form of market pressure from consumers meant that there was benefit in avoiding higher TACs.

2.7.2. Appendix 2.2. Fisheries and jurisdictions that survey respondents are related with

Fishery	Jurisdiction
Abalone	New South Wales South Australia Central Zone South Australia Western Zone Tasmania Victorian Central Zone Victorian Eastern Zone Victorian Western Zone Western Australia
Blue crab	South Australia
Deep Sea Crustacean Managed	Western Australia
Giant crab	Tasmania
Mud Cockle	South Australia
Pink snapper	Western Australia Gascoyne Demersal Scalefish Managed Fishery (Shark Bay)
Eastern rock lobster	New South Wales
Southern rock lobster	New Zealand Cray 5 New Zealand Cray 8 South Australia Northern Zone South Australia Southern Zone Tasmania Victoria Eastern Zone Victoria Western Zone
Western rock lobster	Western Australia

Chapter 3

Changes in the lease and permanent sale quota markets of a rock lobster fishery in response to stock abundance

This chapter previously published as:

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3.1. Abstract

Effective individual transferable quotas (ITQ) systems rebuild stocks and allow transfer of quotas to more efficient operators. This process requires functional markets for both quota sales and temporary quota leases. These markets are expected to respond to changes in economic rent from the fishery, which is influenced by stock abundance and the international rock lobster price. This research used multistate Markov modelling and Granger-causality testing to examine changes in the permanent and temporary quota trade in the Tasmanian rock lobster fishery quota market, during periods of both increasing and decreasing stock abundance. The permanent quota trade market was more active during the period of stock growth while the quota lease market was active in both periods of stock growth and decline. In contrast to theoretical trends in ITQ fisheries, trades in both markets were not linked to the technical efficiency (i.e. catching capability) of operators, but were more driven by the quota owners' financial capacity (i.e. number of owned quotas). Prolonged and unexpected stock decline affected the quota market so that it deviated from the theoretical pattern of ITQ fisheries. Operators previously active in the market reduced their activity while smaller operators and firms that previously had not traded became more active, so the fleet expanded with smaller operators entering.

Keywords: ITQ fishery, owned/fished quotas, temporary/permanent transfers, technical efficiency, Tasmania

3.2. Introduction

Individual Transferable Quotas (ITQ) are an economic instrument that involve the allocation of shares of a total allowable catch (TAC) that can be traded between individuals, typically licence holders. Theoretically, ITQs improve economic efficiency by increasing the incentive to minimize cost, which leads to fleet rationalization (Grafton *et al.* 2000; Costello *et al.* 2008). In order for the ITQ system to produce these outcomes there must be a constraining TAC set by the fishery authority, and a functional market for both permanent transfers (sales) and temporary leasing of quotas, which can lead to an autonomous regulation of the fleet (Kompas *et al.* 2009). It has been shown that ITQ systems are efficient as long as the TAC is set optimally and the quota market is competitive (Clark 1980; Arnason 1990).

ITQ management plans are frequently implemented based on a biological sustainable level (Batstone and Sharp 1999); however, the plans also need to focus on economic rather than biological outcomes. ITQ systems are economic instruments and, management plans should focus on a maximum economic yield as well as maximum sustainable yield (Gardner *et al.* 2015a). Thus, when ITQ systems are operating effectively, stakeholders are motivated to set conservative catch limits so that stocks rebuild and cost of fishing decreases, increasing the value of the quota units on the market (Wilen 2006). A functional market is important for these outcomes because it rewards good decision-making and facilitates quota unit transfers to operators with lower fishing costs who are more able to expand quota ownership. At the same time, the quota market provides incentive for less efficient operators who have higher fishing costs to exit the fishery motivated by the compensation they will receive from the sale of quota.

The transfer of ITQ units in a well-functioning quota market is influenced by many factors including the availability and cost of relevant information to make trading decisions (e.g. price and availability of quota units, number of agents trading, etc.) as well as the cost of the transactions between operators (Rose 2002). The quota price should reflect future cash flows and incorporate expectation of changes in future profitability. This is confirmed by the relationship between stock productivity and both permanent quota sales and temporary quota lease prices (Arnason 1990; Batstone and Sharp 2003; Newell *et al.* 2005). Quota prices are therefore critical for informing operators on decisions of increasing or reducing their ownership of quota units as well as shorter term decisions on leasing quota in or out within a fishing season.

There are many possible barriers to the effective functioning of quota markets including high transaction costs, lack of information, or asymmetrical information flows where some agents have more or better market information than others, creating power imbalances when they trade. The transaction costs of quota owners with a small and medium size holding are mainly associated with brokerage service fees while in the case of quota owners with large holdings these costs include employment of quota managers (Newell *et al.* 2005; van Putten and Gardner 2010). When transaction costs are excessively high, the volume of transactions will fall, leading to noisy price signals and reductions in gains (Stavins 1995). For instance, in the Australian coral reef finfish fishery, unfished quotas were attributed to an imperfect flow of information and high transaction costs, which mainly affected small operators during low quota market activity (Innes *et al.* 2012). Similar problems have also been observed in the Tasmanian rock lobster fishery (TRLF) during a period when the TAC was not entirely caught (non-limiting). At this time, quota owners had imperfect information about profitability in the fishery and priced their quotas at a value that was too high, resulting in a market that did not clear so quota was left untraded and uncaught (Emery *et al.* 2014a).

Quota trading volume may also be affected by a lack of incentives for inactive owners (investors) to sell their quotas, resulting in reduced trade. These quota owners are usually fishers who gradually reduce their fishing effort but remain linked to the fishery by leasing their quota to active fishers (van Putten and Gardner 2010). This gives rise to a situation common to many fisheries where decisions by quota owners are not only driven by profitability of the fisher but also by the desire to avoid capital gains tax, payable on disposal of units (Butler 2004; Pinkerton and Edwards 2009). Consequently, quota units become scarce and small operators struggle to increase their level of ownership. Thus, marginal operators may remain in the fishery preferring to make a smaller profit rather than incur a one-off tax payment (del Valle *et al.* 2008; Pinkerton and Edwards 2009; van Putten and Gardner 2010).

The TRLF examined here has operated under an ITQ management system since 1998, which was introduced in response to declining stock productivity (Bradshaw 2004). The TAC is set annually and distributed equally between 10,507 quota units. Quota units were initially distributed solely on ownership of licences, with no account of catch history. There is no minimum quota ownership, but units can only be fished if associated with a fishing license, owning at least five quota units, and holding a minimum of 15 units. There is also a maximum quota-holding limit of 200 units designed to prevent concentration of ownership. Markets for both sale and temporary lease of quota units have developed with both the number of participants and the number of transactions increasing through time (van Putten and Gardner 2010).

This fishery went through an initial period of rapid stock rebuilding during which biomass and catch rates increased after the introduction of the ITQ system in 1998 until 2006 (Fig. 3.1). Over this period, the TAC was entirely caught and quota lease prices rose (Gardner *et al.* 2011). In the following years the trend reversed and performance indicators steadily decreased as a result of a period of low recruitment (Linnane *et al.* 2010a). The TAC was under-caught in some years and catch rate decreased by 34.2% from 2006 to 2011. This decline was also reflected in declining lease price (Gardner *et al.* 2011).

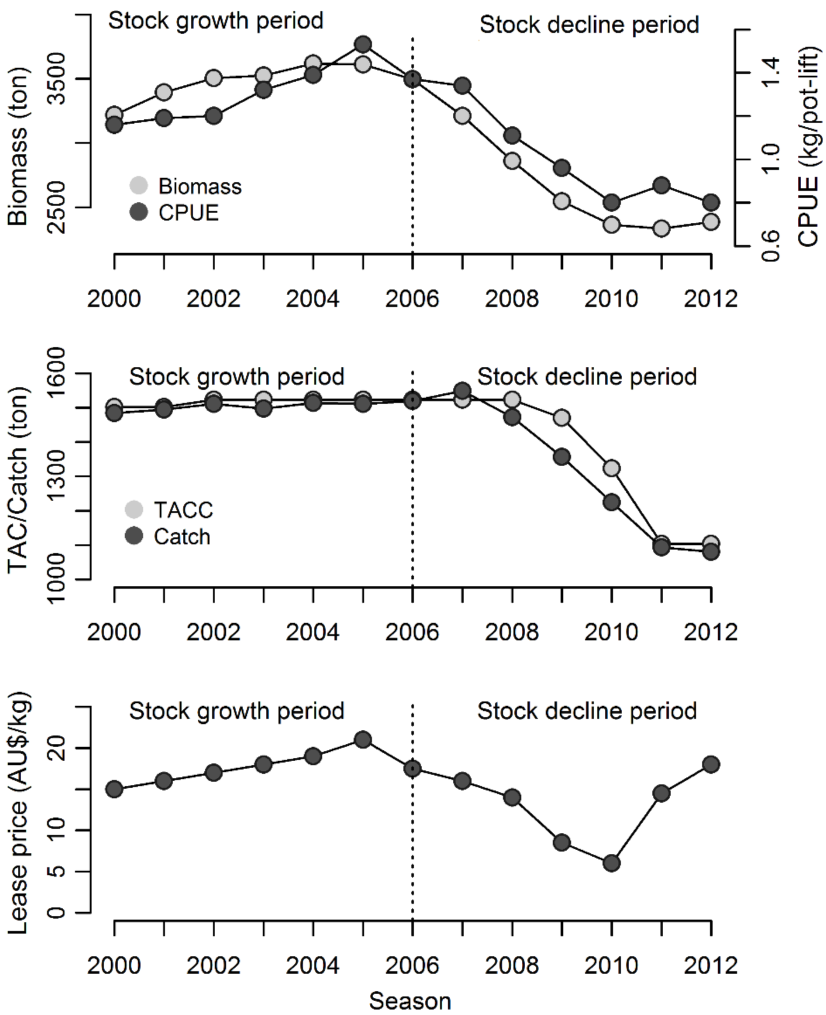


Figure 3.1. Stock status and asset value indicators for Tasmanian rock lobster fishery (Hartmann *et al.* 2012).

Well-functioning quota markets are expected to respond to changes in stock productivity and other economic signals such as beach price and labour costs. Adjustments in the value of quota units are expected to influence changes in quota ownership and the volume of quota traded on the market. The TRLF provided an opportunity to examine whether the permanent sale and temporary lease quota markets responded differently to periods of abundant and depleted stock biomass. The transition rate of quota owners through different levels of ownership and fishing effort was examined to assess whether trading behaviour and trends in ownership responded to changes in stock biomass.

3.3. Methods

Data

Tasmanian rock lobster fishery (TRLF) data were compiled from a database maintained by the Department of Primary Industries, Parks, Water and Environment (DPIPWE), Tasmanian Government. The data comprised information on the number of quota units owned and held (owned + leased in - leased out quotas) per fisher at the end of every fishing season from 2000 to 2012. These are panel data, collected from multiple subjects at the same point in the time at different times in a given period. As the measurements were repeated, subjects showed autocorrelation, and as the subjects interacted with each other, there was also correlation amongst them. The statistical methods explained below are suitable to analyse this kind of panel data. The number of leased in/out quota units per fisher per year was derived by subtracting the number of quota units owned from the number of quota units held. Positive values represented the number of quotas leased in and negative values represented the number of quotas leased out. Two additional variables were used in the analysis, stock status and the individual annual average catch per unit of effort (CPUE; kg per pot lift). The TRLF stock status was categorized into stock growth (2000-2006) and decline (2007-2012) periods.

The CPUE was used as a proxy for technical (fishing/cost) efficiency; despite it being an imperfect measure for comparing individual vessels as their costs may be different (McGarvey *et al.* 2014). Nonetheless, profitability of an individual vessel will increase when CPUE increases for a given set of inputs. Therefore, while CPUE may not capture all the differences in efficiency between vessels, it does represent an important determinant of vessel productivity. In addition to stock abundance, catch rates also vary with, for instance, skipper skill, fishing month, and fishing depth. These factors are taken into account in the standardization of stock assessments in the fishery (Gardner *et al.* 2011). However, these factors are likely to have less of an effect compared with stock abundance (Green *et al.* 2014; Feenstra *et al.* 2014). Additionally, fishing operations are relatively standard in the TRLF as pots dimensions are controlled in the fishery management rules. In the TRLF there is a limit of 50 pots in operation per vessel. Pots are typically set and hauled twice per day. Lobsters can escape so catch rates drop after one day and regulations prohibit leaving pots deployed for longer than 48 hours. Finally, rock lobster price in the Tasmanian fishery is relatively stable and fishers receive approximately the same price for lobsters, because catch is sold to a small number of processors who tend to have the same price although this varies daily and with size and colour of lobster depending on demand from export markets (Chandrapavan *et al.* 2009).

Quota ownership and quota leasing trends

Quota owners were classified into categories according to the number of quota units owned and the fraction leased in/out units relative to their ownership. Quota owner categories were analysed over time to determine trends for the whole fishery in terms of permanent and temporary quota transfers.

Individual quota ownership and leasing transitions

The transition of individual quota owners through different ownership and leasing categories was analysed to examine and deduce collective quota owner behaviour in the sale and the lease markets. Given that the objective was describe the progression of categorical responses variables over time, Multistate Markov (MSM) models were used to describe movements or transitions of quota owners through different states. (Kalbfleisch and Lawless 1985; Jackson *et al.* 2003). Transitions could be in both directions and were expressed as rates; that is, the number of quota owners transiting to another state relative to the total number of subjects in the original state.

In the current study, two MSM models were fitted. The first model was the ownership model where the states represented levels of quota ownership and only involved permanent quota transfers in the permanent sale market. The following four states applied to this model: (i) small owner with between one and 15 quota units; (ii) medium owners with between 16 and 40 units; (iii) large owners with more than 40 units; and (iv) fishers who exited the fishery (Fig. 3.2a). Transition from one ownership state to another represented the sale or permanent transference of quota units, increasing or reducing units owned by a fisher. Stock status and number of fished quotas or catch (owned plus leased in quotas) were used as covariates. The catch of each operator provided a measure of scale of operation and financial capacity.

The second model was the leasing model, where the states represented the temporary (within season) transfer of quota units through the lease market. The five states in this model were: (i) non-leaser, with no participation in the lease market during one or more seasons; (ii) small leasers-out, which were owners who leased out between 1 and 50% of their quota ownership; (iii) large leasers-out, who leased out more than 50% of their quota ownership; (iv) small leasers-in, who leased in between 1 and 25% of their quota ownership; and (v) large leasers-in, who leased in more than 25% of their quota ownership (Fig. 3.2a). Transition from one state to another represented an increase or reduction in the number of leased quotas units traded in the quota lease market relative to the quota ownership because of trading in the quota lease market. In this model, the covariates were stock status and level of quota ownership with ownership a measure of financial capacity. For fishers who transited between states in the leasing model, the average individual CPUE was calculated as an indicator of their technical efficiency.

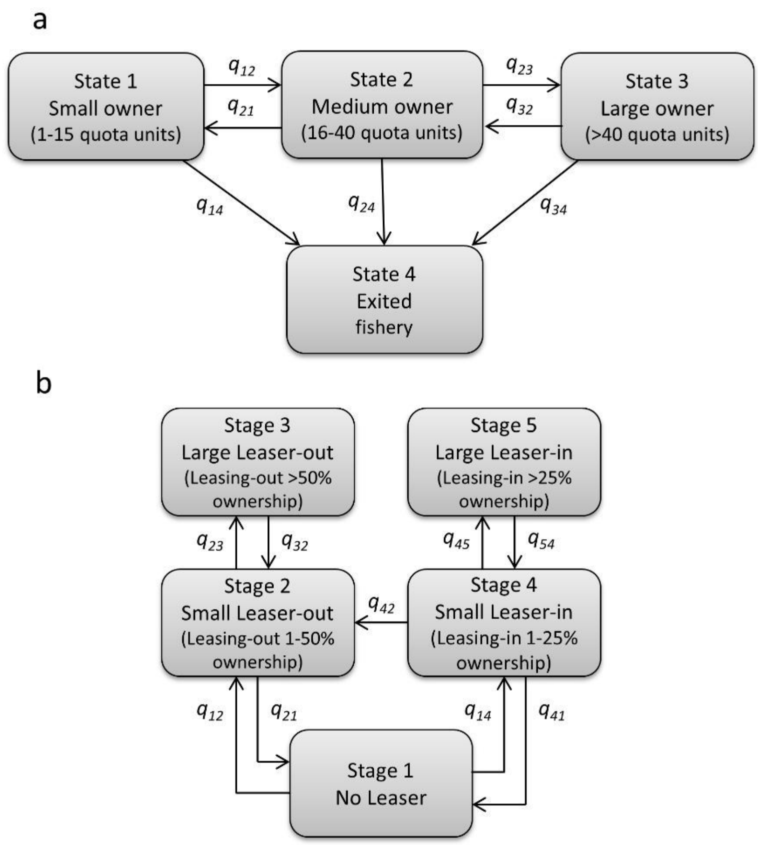


Figure 3.2. Quota ownership (A) and leasing (B) states Multistate Markov model for Tasmanian rock lobster fishery. The transition rates between alternative states are denoted by *q*.

For both models, the threshold between states and the number of states was chosen to ensure an adequate representation of quota transfers. The base criterion used was a sensitivity analysis of the fishers' profit margin to the number of owned and fished quotas in the TRLF (van Putten and Gardner 2010). Different combinations of owned and fished quotas resulted in different levels of accounting profit. The thresholds were adjusted to avoid the transitions being hidden due to the number of quota ownership or leasing transiting being too large. Conversely, if the states covered too narrow a range, any trends in the number of subjects moving from one state to another would be difficult to detect because of small numbers of transitions. Both situations produce convergence failure during the process of rate estimation. Transitions between non-consecutive states were rare across the entire study period and were therefore not considered.

MSM models may be described by transition intensity matrices, where every term is the transition rate (q_{rs}) from one state (r) to other (s) estimated by the maximum likelihood through the R package *msm* (Jackson 2011). For each model, a Pearson-type test was applied to assess the goodness-of-fit that contrast observed versus expected number of transitions between pairs of states and p-values were estimated by parametric bootstrapping (Aguirre-Hernández and Farewell 2002; Titman and Sharples 2010). For both ownership and leasing models there was no significant difference between the observed and expected number of transitions (p=0.079 and p=0.093 respectively).

Transition of quota units to more efficient operators

ITQ systems theoretically result in the transit of quota units to more efficient operators. It was therefore expected that fishers with higher net profit, or those who had been in the fishing sector longer and had more experience, would own and/or lease a larger number of quotas in. A Granger non-causality test was carried out to see whether greater experience and fishing efficiency caused a higher level of quota ownership and/or leasing in. The underlying rationale of this test is that; for instance, CPUE

'Granger-caused' ownership, if the present ownership could be better predicted by present and past CPUE and ownership than by past ownership alone (Lütkepohl 2005).

The Granger non-causality test involves fitting an unrestricted and restricted model (exemplified below) where the hypothesis that CPUE 'caused' the level of ownership (number of owned quotas per operator) was being tested. The unrestricted model included on the right-hand side an endogenous variable, which was the response variable itself lagged p-1 times, the ownership level (y in the equation below); and an exogenous variable, which was an explanatory variable lagged p times, CPUE (x in the equation below) (Erdil and Yetkiner 2004). The restricted model only included the endogenous variable, ownership. The unrestricted model was as follows:

$$y_t = \sum_{m=1}^{p} \beta_m y_{t-m} + \sum_{k=0}^{p} \theta_k x_{t-k} + e_t$$

Where β_m and θ_k were the coefficients of the lagged endogenous and exogenous variables respectively.

The restricted model included only the first part of the right-hand side of the equation; and tested whether or not θ_k coefficients were null, using a Wald test. The hypotheses tested were: i) CPUE "caused" ownership, ii) fished quotas (owned plus leased in) "caused" CPUE, iii) experience (years in the fishery) "caused" CPUE, and iv) ownership "caused" the number of fished quotas. Each hypothesis was also tested in the opposite direction; for instance, ownership "caused" CPUE and so on. Quota owners who were inactive fishers were excluded from this analysis, because there is no data of fishing activity from them. Given that the Granger test involves fitting dynamic models (i.e. with lagged variables), which in general lack of strict exogeneity of regressors and the type of data was panel data, the Generalized Method of Moments (GMM) estimator was applied (Holtz-Eakin *et al.* 1988; Arellano, R., Bond 1991). The GMM models fitting and diagnosis tests were carried out using the R package *plm* (Croissant and Giovanni 2008). The results of this test revealed that the number of owned and fished quotas "Granger-caused" the level of CPUE. Therefore, taking into account that the data were organized in cross sections (data collected from many subjects at the same point in time over a given period of time), a mixed effects model was fitted to describe the effect of ownership and scale of operation on the individual technical efficiency.

3.4. Results

Trends in quota ownership

There was a general trend across the fishery of medium quota owners moving towards either the small or large quota owner groups (Fig. 3.3). Despite the declining trend in the medium ownership group, this remained the largest group in the fishery across the study period. The largest change in the number of quota owners per group occurred during the period of growth in stock and CPUE (2000-2006). During this period the number of medium quota owners dropped by 45 individuals, while the number of small and large quota owners increased by 16 and 25 individuals respectively. This meant that a larger number of medium quota owners acquired additional units in the quota market, relative to those medium owners who sold quota. During the period of decline in stock and CPUE (2007-2012), the number of owners per group remained relatively stationary with the trend similar to the previous period. Transition of quota owners amongst the different states happened from year to year over the whole period of study.

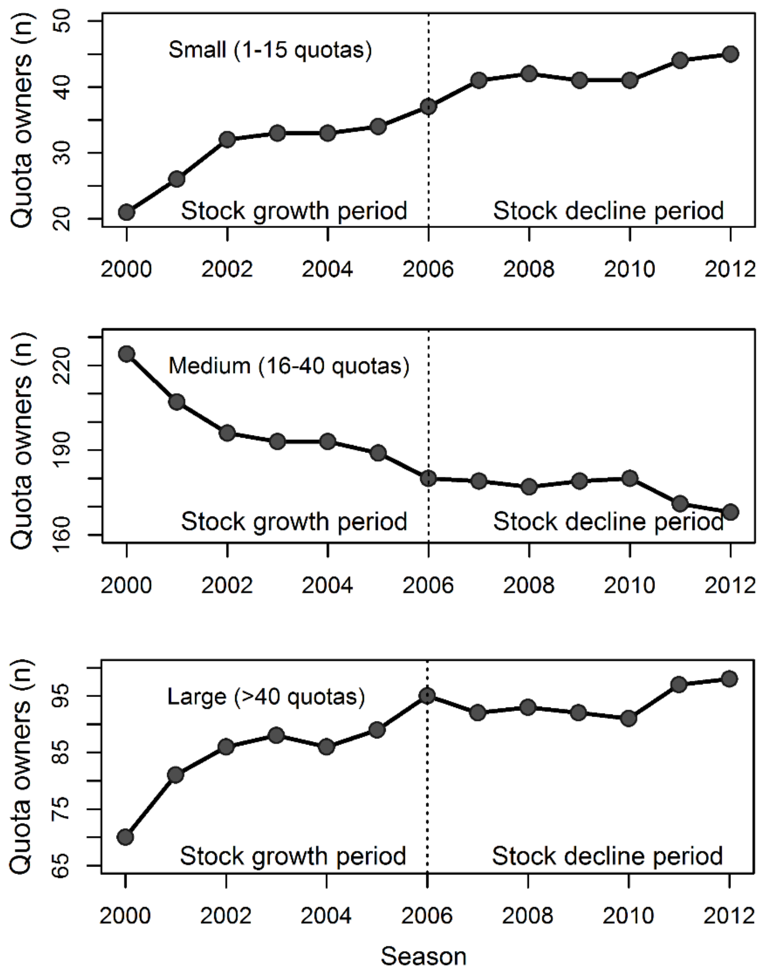


Figure 3.3. Trend over time of quota ownership categories.

Quota ownership transitions through the quota sale market

The largest transition rates amongst different ownership states were observed during the stock growth period, when quota owners were more active in buying and selling quota units. Small and medium quota owners were most active during the time of stock growth. The transition rate of medium quota owners to the group of large quota owners was significantly higher at times of stock growth than in periods of stock decline ($t=3.92$, $p=0.01$, Fig. 3.4a). Small quota owners showed a high transition to the group of medium owners in the stock growth period; however a similar high transition rate was also observed during period of stock decline for this small quota owner group ($t=1.14$, $p=0.31$).

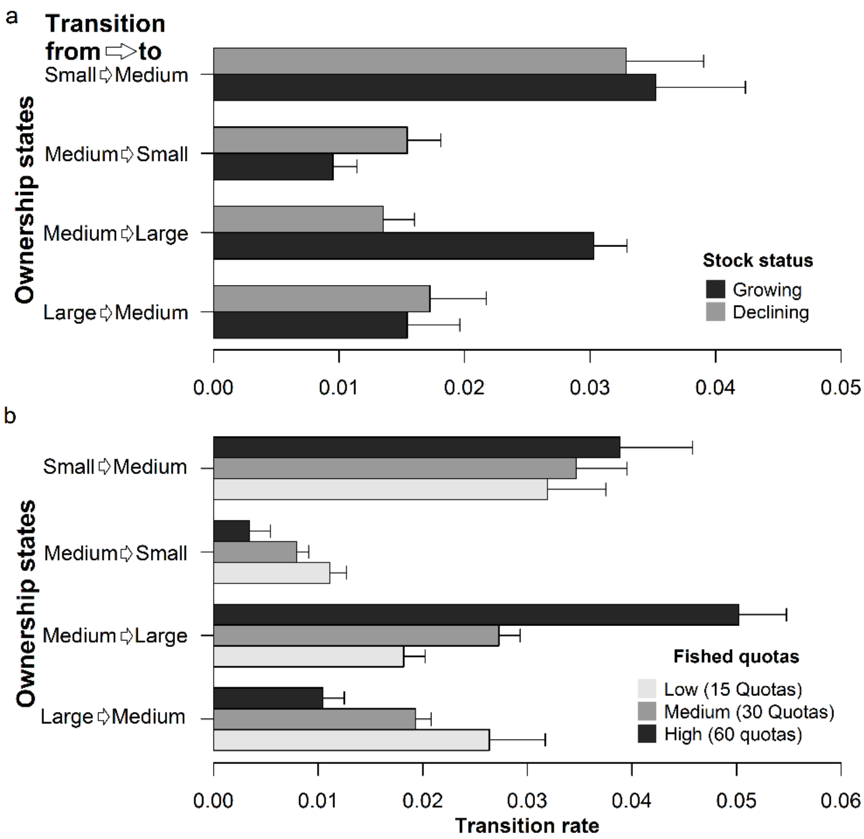


Figure 3.4. Transition rate amongst different levels of quota ownership (a) during the periods of stock growth and decline and (a) for three levels of fished quotas (i.e. total of quota owned and balance of quota leased in and leased out).

Transition of individual operators between different ownership states, in some cases appeared to be influenced by their financial capacity in terms of ownership and number of fished quotas (total owned and leased quota units) and interest in expanding their business. For instance, medium quota owners, who fished a large number of quota units by leasing in additional units, had higher rates of ownership increase than medium owners catching medium or small numbers of quota units (lowest difference $t=4.59$, $p<0.01$, Fig. 3.4a).

Conversely, the upgrading of small to medium quota owners through the quota market did not appear influenced by the presumed lower financial capacity of this group. Small quota owners who fished a small number of units showed a higher upgrading rate than medium owners that also fished a small number of units ($t=3.37$, $p=0.02$, Fig. 3.4a). Additionally, all small owners, increased their ownership at a similar rate regardless of the number of quotas they fished (largest difference $t=1.52$, $p=0.19$).

Rates of exiting the fishery varied with smaller owners exiting the fishery at a higher rate than medium and large quota owners (Fig. 3.5a and b). Ownership categories affected exiting rates (Fig 4a; $t=4.86$, $p<0.01$, $t=5.12$, $p<0.01$ for the test of the two ownership categories with most similar transition rates) and this was not moderated by the stock status ($p>0.05$). In a test of whether both ownership and number of quota fished affected exiting rates, once again it was apparent that ownership affected exiting the industry. A greater number of small owners left (Fig. 3.5b; $t=5.97$, $p<0.01$, $t=4.56$, $p<0.01$ for the test of the categories with most similar transition rates) while the number of quotas actually fished did not influence the exiting rate ($p>0.05$). There was no apparent link between exit rate and individual technical efficiency (CPUE) measured the year before exiting (Table 3.1). Although medium owners who fished more quotas had a significantly higher CPUE relative to medium owners who fished lower number of quotas ($t=2.88$, $p=0.016$), the exit rate remained constant across the medium owners group (medium owner who fished higher vs. lower number of quotas $t=1.42$, $p=0.21$).

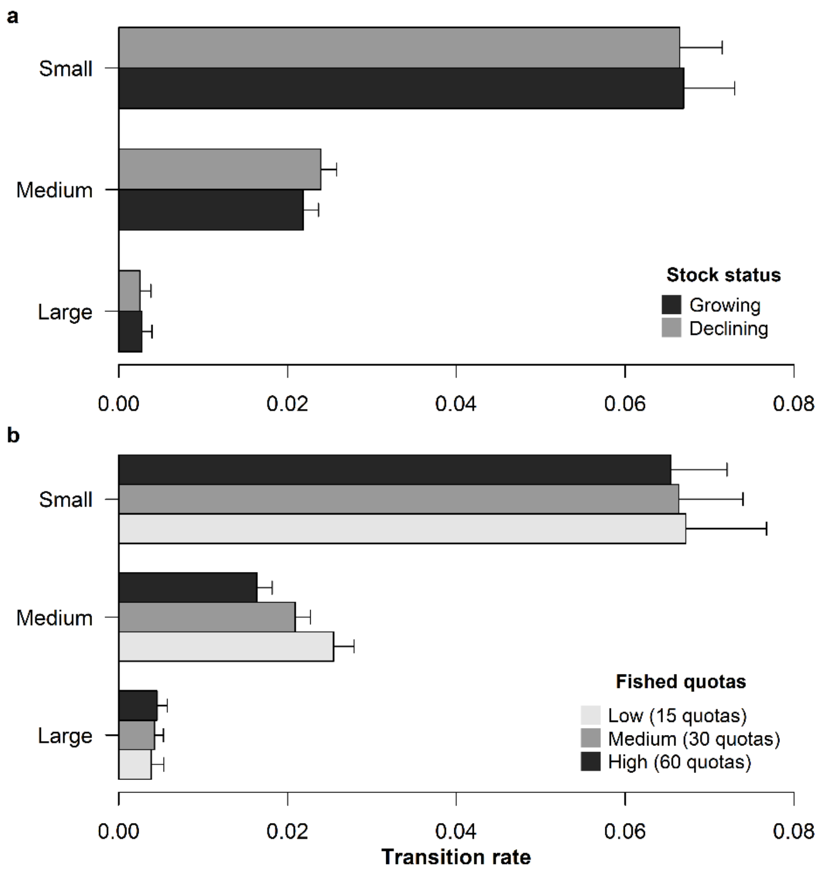


Figure 3.5. Fishery exit rate for three different levels of quota ownership (a) during the period of stock growth and decline and (a) for three levels of fished quotas (i.e. the sum of quota owned and the balance of quota leased in and leased out).

Table 3.1. Average CPUE and Standard deviation in parentheses for small, medium and large quota owners for different catch levels the year before to exiting the fishery.

Catch level (Number of fished quotas)	Small	Medium	Large
Low (15-20)	0.86(0.28)	0.81(0.44)	-
Medium (21-40)	0.95(0.27)	0.80(0.20)	1.53(0.81)
High (>40)	1.10(0.26)	1.17(0.10)	1.80(0.84)
$t_{\text{Low vs Medium}}$	0.69(0.500)	0.38(0.709)	-
$t_{\text{Low vs High}}$	1.93(0.074)	1.78(0.106)	-
$t_{\text{Medium vs High}}$	1.26(0.227)	2.88(0.016)	0.43(0.698)

Pairwise t test to assess difference of CPUE amongst the three catch levels, p-values in parentheses.

Trends in quota leasing activity

Variation in leasing activity could be categorized into four stages. Through the period of stock growth (2000 to 2006), the number of operators who did not participate in the lease market (non-leasers) declined during the first three years. An additional 20 operators who previously did not trade quota units, became active in the leasing market (Fig. 3.6). During the second part of the stock growth period (2004 to 2006), there were no changes in the number of operators leasing quotas units. During the first two years of the stock decline period (2007 to 2012) 16 additional operators who did not previously trade quota units entered the leasing market. The following years in the period of stock decline the number of operators who leased quotas remained approximately constant.

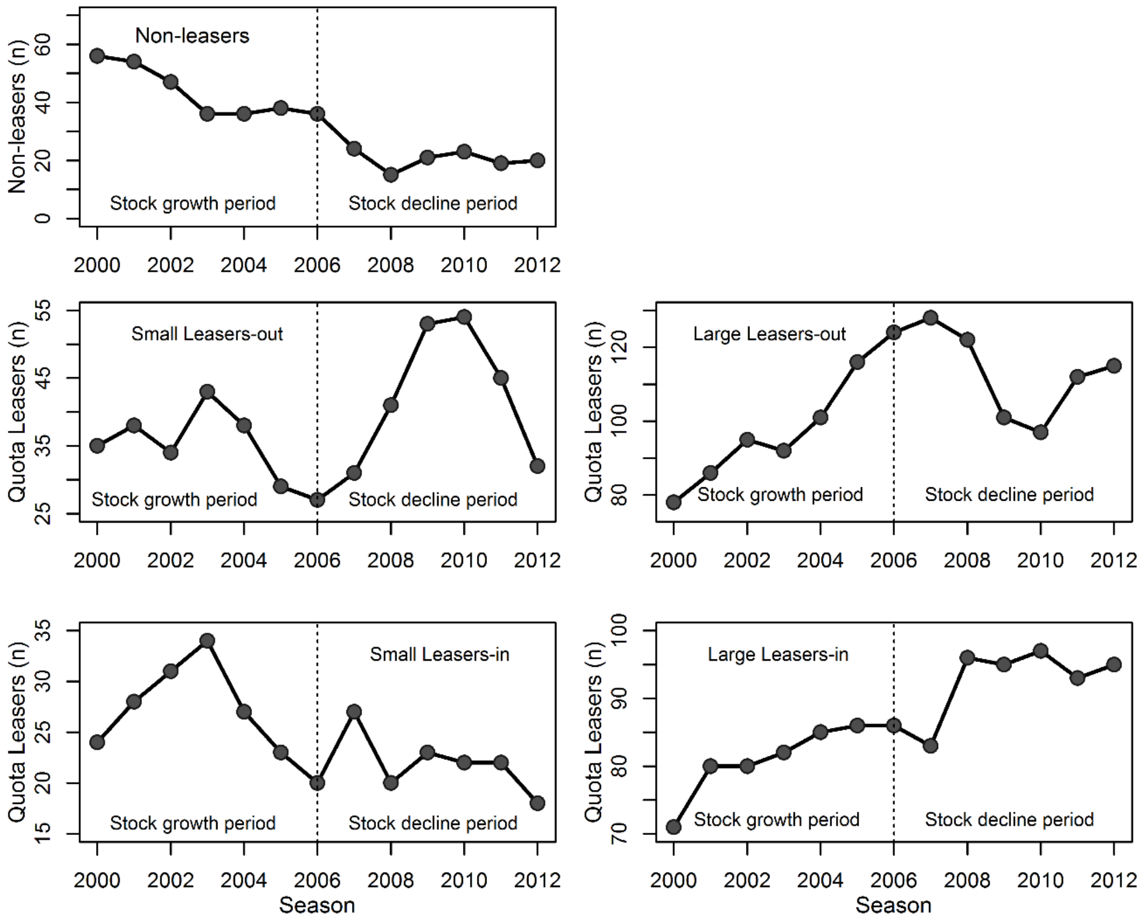


Figure 3.6. Trend over time of leasing categories and catch rates (CPUE).

The leasing activities of small leaser-in and small leaser-out on the quota market showed two different tendencies during the period of stock growth (Fig. 3.6). Before 2003 the number of operators who leased a small number of quotas in and out showed an increasing trend which peaked in 2003. After 2003, the number of small leaser-in/out decreased, reaching a minimum in 2006, just when the stock reached a maximum. In contrast, the number of large leaser-in/out steadily increased during the period of stock growth, reaching a maximum in 2006.

Throughout the period of stock decline, the trend in the number of large leasers-out followed the same pattern as the stock abundance (Fig. 3.6). In contrast, the number of small leasers-out followed an opposite pattern. The number of small leasers-out peaked in 2010, just when the stock abundance reached a minimum and, in the following two years, the number of small leasers-out declined while the stock showed signs of rebuilding. The number of large leasers-out peaked in 2007, decreased after that and reaching a minimum in 2010. The numbers began to increase again after 2010, when the stock began to rebuild. In the period of stock decline the number of leasers-in remained approximately constant. During this stock decline period the number of large leasers-in reached a maximum in 2008 and remained approximately constant after that.

Rates of transitions in number of fished quotas

Changes in the stock status appeared to have greatest impact on non-leasers and small leasers-in. Non-leasers became active in the lease market in greater numbers during the period of stock decline than the period of stock growth. Non-leasers transited to become small leasers-out ($t=3.05$, $p<0.01$) and small leasers-in ($t=2.28$, $p=0.03$) (Fig. 3.7a). In the opposite direction transitions also occurred, where small leasers-in left the quota lease market to become non-leasers. This transition from small leaser-in to non-leaser was higher during the period of stock decline than during the period of stock growth ($t=2.84$, $p<0.01$).

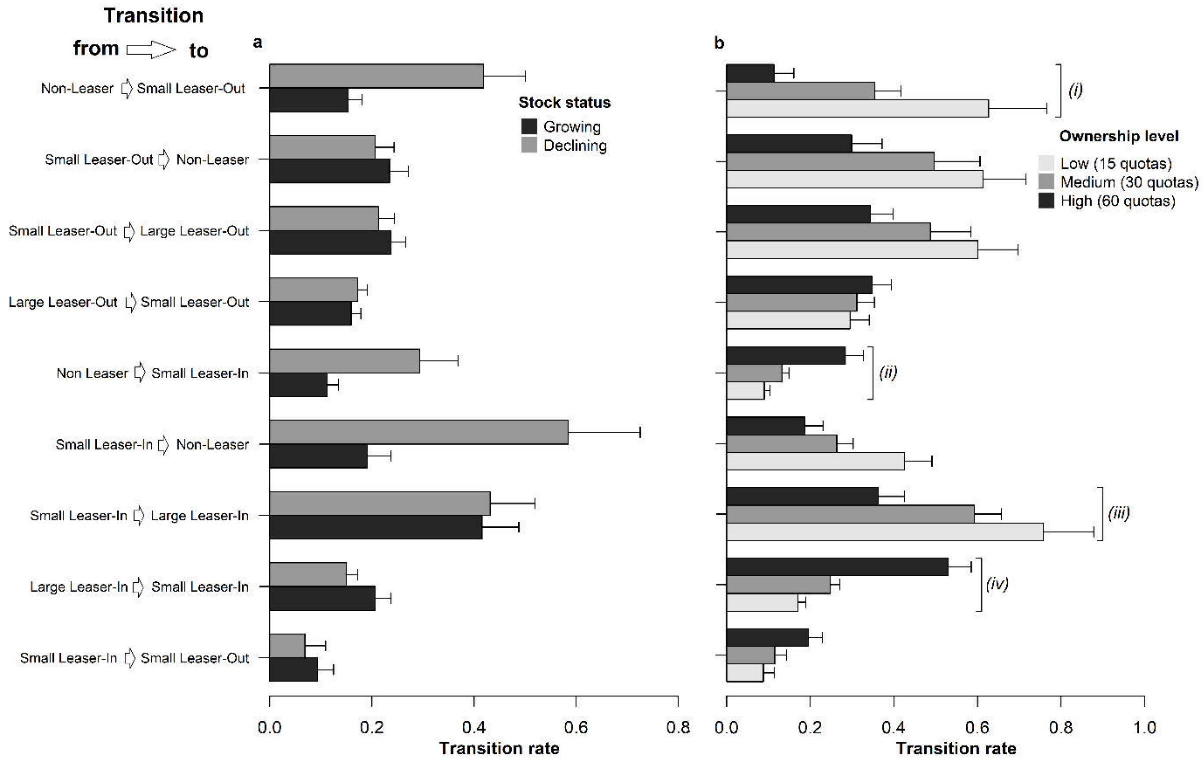


Figure 3.7. Transition rate amongst different levels of quota leasing (A) during the periods of stock growth/decline, and (B) for three levels of quota ownership. Significant differences in transition rates through leasing states at the three ownership levels: (i) low-high t=4.48 (p<0.010), medium-high t=2.66 (p=0.012); (ii) small-large t=4.29 (p<0.010), medium-large t=3.29 (p<0.010); (iii) small-medium t=3.32 (p=0.025), small-large t=2.94 (p<0.010), medium-large t=2.54 (p=0.014) and (iv) small-medium t=2.63 (p=0.014), small-large t=6.04 (p<0.010) and medium-large t=4.62 (p<0.010). No significant differences found in transition rate amongst ownership levels not numbered.

The level of quota ownership affected almost 50% of the transitions between different states of quota leasing. Apparently, operators tried to reach a balance between owned and leased quotas. For instance, there was a significant decrease in the transition rate from small leaser-in to large leaser-in while quota ownership was high (Fig. 3.7b). In other words, operators were less likely to lease additional quotas if they owned a large number of quota units. Operators were also more likely to lease quotas units out when they owned greater number of units. Thus, operators who transited from being a large leaser-in to small leaser-in showed a significative decrease in the transition rate when the number of owned quotas was low.

There did not appear consistent pattern in the transition between the rate of quota leasing and the efficiency of quota owners as indicated by their CPUE. Large quota owners, who had a significantly higher CPUE than small operators during the year before to move to other estate ($t=3.23$, $p<0.01$, Table 3.2), had a higher transition when moving from being a non-leaser to a small leaser-in ($t=4.29$, $p<0.01$) (Fig. 3.7b). This result indicated that the expected higher transition of leased in quotas by more efficient operators was met. However, this pattern did not apply for the remainder of the quota owners involved in the quota lease market. For instance, with respect to quota that is leased out, small quota owners had a significantly higher transition rate than large quota owners when moving from non-leaser to being a small leaser-out ($t=4.48$, $p<0.01$) (Fig. 3.7b). However, small quota owners who leased out had significantly lower CPUE than large quota owners who leased out ($t=6.80$, $p<0.01$). In this case, the results suggested that quotas were transiting to less efficient operators.

Table 3.2. Average CPUE of quota owners for small, medium and large quota ownership the year before transiting for different leasing states. Standard deviation in parentheses. T test between small and large ownership.

Transition (from→to)	Quota ownership			t	p-value
	Small	Medium	Large		
Non-leasers→small leasers-out	0.54(0.19)	1.00(0.34)	1.20(0.34)	6.80	<0.010
Small leasers-out→non-leasers	0.73(0.28)	0.91(0.41)	1.05(0.26)	2.79	0.011
Small leasers-out→large leasers-out	0.66(0.54)	0.87(0.43)	1.20(0.63)	3.85	<0.010
Large leasers-out→small leasers-out	0.51(0.41)	0.93(0.42)	1.08(0.66)	3.64	<0.010
Non-leasers→small leasers-in	0.70(0.10)	0.97(0.54)	1.09(0.30)	3.23	<0.010
Small leasers-in→non-leasers	1.03(0.63)	0.89(0.36)	1.03(0.25)	0.48	0.637
Small leasers-in →large leasers-in	0.67(0.19)	1.03(0.27)	1.19(0.46)	5.17	<0.010
Large leasers-in→small leasers-in	0.69(0.33)	1.02(0.30)	1.30(0.39)	5.55	<0.010
Small leasers-in→small leasers-out	0.39(0.04)	1.03(0.61)	1.18(0.52)	12.91	<0.010

Transition of quota units to more efficient operators

The expected Granger-causal relation between efficiency as measured by CPUE and quota ownership/number of fished quotas was observed during the period of stock growth but was absent during the period of stock decline (Table 3.3). In other words, operators who were more efficient owned/fished more quota units during the period of growth, but this did not hold during the period of decline. In addition, a Granger-causal relation was also found in the direction from ownership/number of fished quotas to CPUE during both periods (Table 3.3). This is to say, operators owning and fishing a larger number of quota units are more likely to be more technically efficient. A second proxy used for efficiency was fishing experience (number of years operation in the fishery) and this did not Granger-cause levels of quota ownership or number of fished quotas during both periods. Therefore, any experience gained through the time operating in the fishery did not ensure a higher ownership or a higher scale of operation. The results also showed that the number of quota units owned Granger-caused the number of quotas units fished and not the other way around, during both periods (Table 3.3). This meant that operators who owned a large number of quota units were more likely to increase their scale of operation, but operators who fished a large number of quota units did not necessarily increase their ownership.

Table 3.3. Results of the Wald test to establish causality and find proof that changes in one variable "caused" changes in another variable. "Causes"= "Granger-causes".

Hypothesis	Stock growth period			Stock decline period		
	W	*p*-value	Granger causality? †	W	*p*-value	Granger causality? †
Changes in CPUE efficiency "causes" changes in quota ownership	9.53	0.039	Yes	4.26	0.422	No
Changes in quota ownership "causes" changes in CPUE efficiency	38.39	<0.001	Yes	20.32	<0.001	Yes
Changes in experience "causes" changes in quota ownership	0.09	0.914	No	0.55	0.650	No
Changes in CPUE efficiency "causes" changes in number of fished quotas	14.29	0.003	Yes	6.16	0.089	No
Changes in number of fished quotas "causes" changes in CPUE efficiency	65.69	<0.001	Yes	30.82	<0.001	Yes
Changes in quota ownership "causes" changes in number of fished quotas	6.78	<0.001	Yes	3.76	0.011	Yes
Changes in number of fished quotas "causes" changes in quota ownership	4.90	0.311	No	0.67	0.946	No

† At 95% of significance.

3.5. Discussion

ITQ systems are intended to increase economic efficiency through fleet rationalization and also provide incentives to manage harvests conservatively (Grafton *et al.* 2000; Costello *et al.* 2008; Kompas *et al.* 2009). To deliver these changes, ITQ systems require a functional quota market that reflects changes in rent from the fishery due to changes in stock abundance (Newell *et al.* 2005; Grafton *et al.* 2006), and facilitate quota transfers to technically efficient operators. The results of this study revealed that during the period of stock decline quota transfers were not necessarily a consequence of technical and economic efficiency; instead, technical and economic efficiency were a result of the financial capacity of operators, measured in terms of quota ownership and number of fished quotas. There are other potential exogenous factors not examined here that could also affect transition rates and would be of interest for further research. For example, quota ownership and the scale of operation may respond to changes in price, labour costs, and integration between processors and fishing operations.

The quota sale market showed a higher level of activity during periods of stock growth, which was evident in the change of the fishery's ownership structure. Some of the medium quota owners reduced ownership while others with a high catch level (through both owned and leased quota) acquired additional units in the quota market to become large owners. Higher rent signalled through higher catch rate (Newell *et al.* 2005), and higher quota value achieved by sound TACs (Arnason 1990), were incentives to buy additional quota units for medium quota owners. This group of medium quota owners were more able to afford additional quota units and increase the scale of their operation; thereby increasing their rent by reducing quota lease cost. They can also become income supplementers or investors, by leasing out a fraction of their total number of quota units (van Putten and Gardner 2010).

Like medium size quota owners, small quota owners responded to the incentives produced by higher catch rates during period of stock growth, showing a high transition rate from small to medium size quota owners. Small quota owners have pressure to increase their ownership relative to the number of quota units that are leased in, because the lease cost is a large proportion of the value of the catch. During the period of stock growth, the leasing price increased as a percentage of the ex-vessel value of the catch from 40% in 2001 to 64% in 2005 (Emery *et al.* 2014b). This was a strong incentive for small quota owners to find mechanisms to finance new quota units and reduce lease costs, thus increasing the probability they could stay financially viable and remain in the fishery.

Quota market activity fell during the period of stock decline with fewer permanent transfers and stability in the number of quota owners in most ownership groups. Through this declining stock period active owners appeared to have less incentive to increase quota ownership because of lower profit expectations signals from lower catch rates. In the TRLF fishers generally adjust their daily effort according to changes in the expected catch rates, particularly during a period of stock decline (Emery *et al.* 2014a). In addition, during the period of stock decline there was less incentive to trade quota for income supplementers or investors because lease price fell. This fall in lease price is particularly dramatic if the TAC is set too high and becomes non-limiting. Therefore, at those times there was less incentive for active quota owners to buy additional quota units and take the risk of not being able to catch this additional quota. There was also less incentive for income supplementers or investors to lease out quotas due to the low price.

Despite the reduced activity in the quota market during the period of stock decline, small quota owners had a high rate of ownership increase. Regardless of low catch expectations, some bought additional quotas and increased their holdings while the quota unit price was low. In this case, small operators increased ownership overcoming usual barriers such as asymmetric market information and competition with larger quota owners with a higher bargaining power (McEvoy *et al.* 2009; Pinkerton and Edwards 2009).

Quota markets in ITQ systems are expected to facilitate quota units transiting from less to more efficient operators (Uchida *et al.* 2004) creating an overall reduction in cost through fleet rationalization (Arnason 1993; Newell *et al.* 2005). In the TRLF, the Granger causality test indicated that changes in the ownership and number of fished quota were linked to the technical efficiency of fishers during the period of stock growth, but this 'causal' effect was not found during the period of stock decline. Fleet rationalization occurred at the beginning of the stock growth period, when the number of active vessel declined by 25% from 325 in 1997 to 242 in 2000 (Hamon *et al.* 2009; Hartmann *et al.* 2013). This was driven by an overall increase in stock and it was reflected in the 'causal' relation between the individual technical efficiency and the number of owned and fished quotas. Although technical efficiency seemed to affect changes in quota ownership and number of fished quotas, one interesting trend that was apparent from Granger causality was that operators who owned a large number of quota units were more likely to increase their ownership and number of fished quotas further, during both periods. This suggested their ability to expand ownership was due to their larger financial capacity, which has affected changes in ownership elsewhere (Sumaila and Watson 2002; Pinkerton and Edwards 2009).

Exit from the fishery was also related to the financial capacity of operators in terms of owned quotas rather than their technical efficiency. In the Tasmanian RLF, operators fishing less than 25 quota units are not able to remain in the fishery even in the short term because of a lower accounting profit (van Putten and Gardner 2010). Therefore, small quota owners tried to increase their accounting profit leasing in additional quotas; however, the leasing cost lowered their accounting profit. Consequently, they were more likely to exit the fishery than other categories of fisher. This trend has been observed in other fisheries and can be moderated by levels of debt (Davidson 2010). Thus, any cost reduction as a result of higher technical efficiency measured in terms of CPUE could not offset the significant cost of leasing in extra quotas.

Like the quota sale market, the quota lease market also responded to stock changes. During the stock growth period, there were increases in the number of participants and increases in the connectivity of the lease market with trades occurring through a wider network (van Putten and Gardner 2010). The participation of small leasers-in fell as the stock and lease price grew, especially between 2004 and 2006 when the lease quota price had risen by 62% from initial levels. This suggested that the small leasers-in group had a lower financial capacity and were less able to compete in the lease quota market as prices rose. In contrast, large leasers-in grew through the period of stock growth (2000-2006). This pattern in the lease market was consistent with our results from the 'causal' effect of quota ownership on number of fished quotas, which also drove patterns in the TRLF fleet during stock growth between 2001 and 2007, which showed quota concentration (Emery *et al.* 2014a).

The quota lease market behaved differently according to trends in the stock and was moderated by the financial capacity of operators, as indicated by their level of leased quotas. This observation was also apparent in the absence of a 'causal' link between technical efficiency and number of fished quotas. Therefore, the composition of participants changed as the stock declined. There was a decline in the number of large leasers-out, who dominated during the period of stock growth, and there was an increase in participation by operators who had previously not been active in the lease market. This was consistent with a pattern of a large fleet and less concentration of catch during stock decline (Emery *et al.* 2014a).

3.6. Conclusion

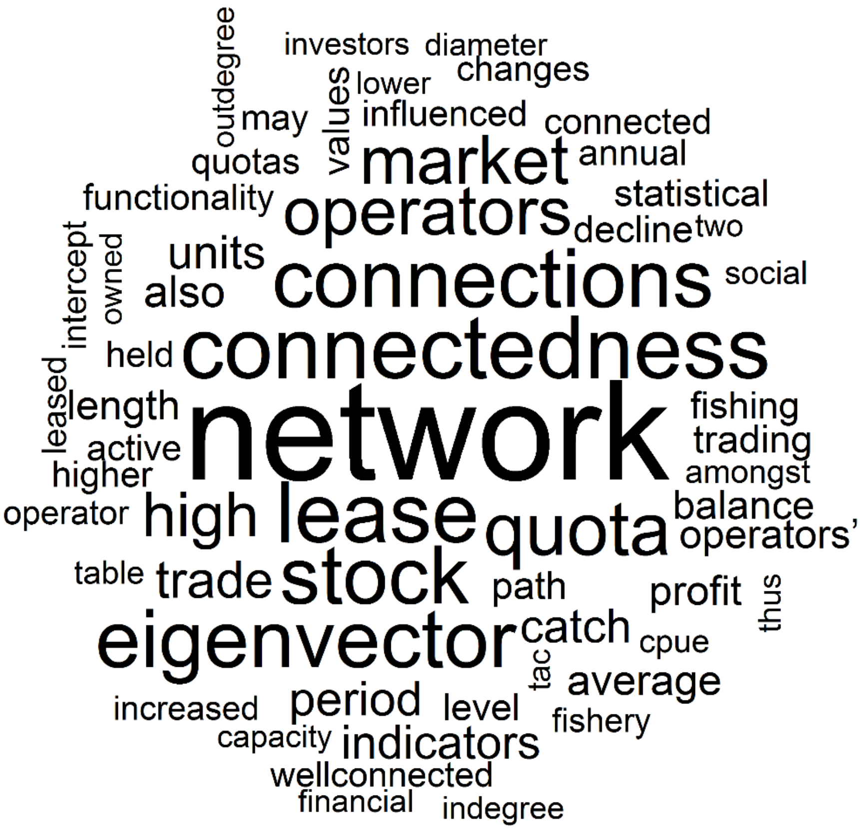
The quota market in the TRLF responded to changes in stock abundance that occurred because of temporal fluctuations in recruitment (Linnane *et al.* 2010a), with a larger number of permanent quota transfers during the period of stock growth and a lower number as stocks declined. At times of stock growth, when expectations of future profit were high, quota owners increased the scale of operation, and/or became investors or income supplementers. The permanent transfer of quota units in this fishery was not connected to the quota owners' technical efficiency, but was driven by their financial capacity and to a lower extent by their scale of operation. Similarly, exiting the fishery was not associated with the fishers' technical efficiency, but their financial capacity - those who owned fewer quotas were more likely to exit the fishery. These outcomes were not consistent with one of the intended outcomes of ITQ systems, which is to increase the technical efficiency of the fleet through transfer of quota units between operators in a market.

Trends in stock abundance also affected trade in the quota lease market. In this market, there was no reduction in overall leasing activity during periods of stock decline although the activity of different categories of fisher changed. Lease quota units transited towards operators with a higher financial capacity and not necessarily toward those who were more technically efficient. When the stock declined the composition of participants changed, with a decline in operators who leased a large number of quotas units and an increase in operators who leased a small number of units.

This research shows that temporary and permanent quota markets are complex and can be affected by temporal patterns in stock recruitment and productivity. Consequently, unexpected changes in the stock, together with the heterogeneity in business structures between operators in the fleet may result in changes different from that expected from ITQ theory. Periods of stock decline resulted in fleet renewal and expansion rather than accumulation and concentration. Further, the trades made in the quota sale and quota lease markets did not result in a shift in catch towards operators with greater technical efficiency.

Chapter 4

Changes in leasing network of rock lobster quota in response to stock abundance



4.1. Abstract

Good decisions on stock management in individual transferable quota (ITQ) systems are rewarded in markets where quota units are transferred to more efficient operators. These markets are expected to respond to variations in economic rent from the fishery, which in turn are influenced by stock abundance and external factors such as exchange rates and price. This research used a social network approach to examine the functioning of the quota lease market functionality in the Tasmanian rock lobster fishery, during periods of both increasing and decreasing stock abundance. The influence of operational fishing factors on operators' connectedness, and the influence of connectedness on the success of operators in terms of quota balance and profit, was examined using linear mixed effect modelling. When the stock biomass increased, operators increased their one-way or reciprocal trade connections with the result that the complexity of their trade network increased. The connectedness of active operators was mostly influenced by their fishing operation characteristics, while quota ownership was the main factor in the case of investors. Different dimension of social capital influenced success in the fishery for active operators and investors. The response of operators to changes in stock recruitment and productivity was variable and mainly affected by business structure, financial characteristics, and bargaining capacity.

Keywords: Network analysis, connectedness, market functionality, ITQ

4.2. Introduction

The economic benefits of Individual Transferable Quota (ITQ) systems are derived from reductions in cost, through the elimination of wasteful effort, higher catch rates, and market-based rewards for good decision making on stock management (Grafton *et al.* 2000; Costello *et al.* 2008). When governments make sound decisions setting the Total Allowable Catch (TAC), higher profitability expectations should be reflected in both permanent quota sales and temporary quota lease prices (Arnason 1990; Batstone and Sharp 2003; Newell *et al.* 2005). This is thought to align industry's interest with long-term fishery management objectives, which makes it easier for governments to make responsible decisions.

Quota prices and markets are thus critical to achieving the theoretical benefits of providing industry incentives with ITQs. Quota markets facilitate permanent and temporary transfers of quota units to operators with lower fishing costs. Simultaneously, high quota sale prices in quota markets may provide incentives for operators with high fishing costs to exit the fishery.

Permanent and temporary transfers of quota units in an ITQ market are influenced by a number of factors, such as availability and cost of relevant information to make trading decisions (e.g. price and availability of quota units, number of agents trading, etc.) as well as the transaction costs between operators (Rose 2002). Ultimately functioning of the market for quota is critical but this may fail to result in transfer of quota transfers to more efficient operators for many reasons, including heterogeneity amongst operators in bargaining power, transaction cost barriers, and inaccessibility of market information (Stavins 1995; Anderson 2008). The influence of these factors may be affected by the structure and dynamics of connections amongst trading partners in a market. Therefore, market functionality may be explored by analysing the trade network created by market participants and their trading connections. Trade networks also reflect the social interactions in markets, which are known to alter the economic behaviour of operators (Podolny 2001; Fligstein and Dauter 2007; Bögenhold 2013; Jackson 2014).

Social networks, together with norms of trust and reciprocity, are important components of social capital (Grafton 2005). Social network is a multi-dimension concept that included both structure of social connections and the quality of these connections amongst actors. Thus, on the basis of an actor's social connectedness, an actor may be rewarded for being connected with other actors in a network (Portes 1998). Chances of success are increased when the number of connections also increases, as the opportunities and capacities are enhanced. Thus, in the context of ITQ markets, operators that are well connected with others may be expected to have greater ability to access quota when they wish to make changes to their business to maximize their profit. This means that a higher level of connectedness may lead to higher individual profit (Turner *et al.* 2014), and from a collective point of view it may lead to a higher market functionality and lower rent dissipation (Innes *et al.* 2014). Social network is formally split into three categories: bridging, linking, and bonding social capital (Woolcock 2001). Bridging involves connection between similar but different groups, and linking involves with connections between disparate groups with different hierarchies. The last category, bonding social capital, refers to connections amongst individuals within groups, was the focus of the analysis conducted here and hereinafter referred as connectedness.

This research was focused on the lease quota trade market of Tasmanian rock lobster fishery (TRLF), which has operated under an ITQ management system since 1998. The TAC is set annually and distributed equally between 10,507 quota units. Markets for both sale and temporary lease of quota units have developed with both the number of participants and the number of transactions increasing through time (van Putten *et al.* 2011). This fishery went through an initial period of rapid stock rebuilding during which biomass and catch rates increased after the introduction of the ITQ system in 1998 until 2006, stock growth period (Fig. 3.1). Over this period, the TAC was entirely caught and quota lease prices rose (Gardner *et al.* 2011). In the following years the trend reversed and performance indicators steadily decreased as a result of a period of low recruitment (Linnane *et al.* 2010c), we refer to this as the stock decline period. The TAC was under-caught in some years and catch rate decreased by 34.2% from 2006 to 2011. This decline was also reflected in a declining lease quota price (Gardner *et al.* 2011).

Stock declines that have occurred since 2006 provided a perturbation to this market. Uncertainty around future catches and associated higher fishing costs is known to lead to operators changing their trading behaviour (Lindner *et al.* 1992), which may be reflected in their lease quota trade connections. Change in lease trading relative to stock biomass was examined here with a social network approach.

4.3. Methods

Data

Quota trading data for the TRLF was compiled from a database maintained by the Department of Primary Industries, Parks, Water and Environment (DPIPWE) of the Tasmanian Government. Data from 2000 to 2012 comprised information on quota transactions: who leased (in/out) to whom, number of quota units owned and held (owned +leased in - leased out quotas) per fisher at the end of every fishing season. The number of leased in/out quota units per fisher per year was derived by subtracting the number of quota units owned from the number of quota units held. Positive values represented the number of quotas leased in while negative values represented the number of quotas leased out.

Additional covariates were obtained from the database or stock assessments of the fishery (Hartmann *et al.* 2012) to assess their relationship with the changes in the structure of the lease quota trade network. Fishery-based covariates were average annual catch per unit effort (CPUE; kg per pot lift), biomass (exploitable biomass, ton) and recruitment (total number of puerulus) as a proxy for stock status. Operator-based covariates were the individual CPUE, annual individual catch (as a fraction of weight of held quota, in kg), fished quota (weight of held quota as a fraction of the TAC), overall length (m) of vessels and quota ownership (weight of owned quota as a fraction of the TAC).

Changes in trading in the lease quota trading network

Changes in the lease quota market network was examined by mapping each fishing season where vertices (nodes) represented operators leasing quota units, and edges (ties) represented temporary lease quota exchanges between operators. Both vertices and edges had attributes; for example, the number of owned quota units was a vertex attribute and the number of units transferred between two vertices was an edge attribute. Operator-based covariates were used as vertices' attributes. The annual lease quota trade network maps took into account the direction of quota transfers; thus, some vertices had edges coming in, out or both when actors leased in, out or both in and out respectively. From each annual network, information about the network structure and operator connections was extracted calculating an annual average of vertex and network-based statistical standardized indicators (Table 4.1), which were estimated using the R package *igraph* (Csárdi and Nepusz 2006).

Table 4.1. Statistical network indicators.

Dimension	Statistical indicator	Definition	Description
	Density	Ratio of the number of edges in the network over the total number of potential edges.	A well connected network has a high density. In a lease quota market this implies that operators are trading with a large number of operators who are also trading with a large number of other operators. Thus it is more likely that they are able to lease in/out required quota.
Network	Average path length	Average of the shortest path between every vertex pair with the minimal number of vertices between them.	Average distance between any two operators. Networks where the path length is long means that an individual needs to pass through many others to interact with a given individual. High values are more frequent in networks with less randomness.
	Diameter	The longest distance between the shortest paths with two connected vertices.	Indicates how long it will takes to reach any vertex in the network. This indicator has a similar interpretation to the average path length.
	Degree centrality	Number of edges associated with a vertex, with in-degree when the vertex receives the information and out-degree when this delivers the information.	Number of operators who a quota owner trades with. In-degree is the number of trades where an operator leases in quota units and out-degree where an operator leases out units. An operator with a high in-degree value leases quota from a large number of suppliers. This enriches their connectedness, as a high number of connections increase the probability of being able to trade all desired quota. Likewise, an operator with a high out-degree has high probability of leasing out desired quota.
Vertex	Between-ness centrality	Extent to which a vertex is located between other pairs of vertices.	Indicates the probability that an operator is on the most direct route between other two operators. Usually, operators with high betweenness are in the path between two or more groups of operators that are well-connected. Thus their role in the network is to create a bridge to other operators on the shortest path.
	Eigenvector centrality	Extent to which a vertex is connected to others well connected vertices.	This indicator is a measure of whether an operator is a “big fish” connected with other “big fish” in the network. Operators with high eigenvector scores have many connections and are connected with other operators who also have many connections. It is likely that they have high financial capital, own and trade large number of quotas, and are likely to succeed in the market.

The influence of the stock status on the network structure was explored modelling the annual average CPUE, the exploitable biomass and recruitment (total estimated number of puerulus) versus annual network indicators (network density, average path length and network diameter). Lease quota price was also used as it is expected to respond to stock status in a well-functioning market (Arnason 1990). In each case interactions were explored. Linear models were fitted using Generalized Least Squares (GLS), to take into account autocorrelation between years (Zuur *et al.* 2009).

Connectedness and market functionality

The operators' connectedness was determined from statistical indicators of each operator (in/out degree, betweenness and eigenvector). The balance between operators' annual owned and leased in/out quota was used to assess the efficiency of the TRL lease quota trade market. In a functional quota system, operators cover their catch with quota that they own and also by leasing in/out units as required. Additionally, the operators' annual profit was used to measure market efficiency, because this was influenced by their balance of quota. To examine differences amongst operators, operators were first classified using a typology simplified from van Putten and Gardner (2010): (i) active operators, who fished and traded quota in the lease market, and (ii) investors, who did not fish but were involved in quota trades in this market. The effect of characteristics of operators on connectedness was also modelled using variables of individual CPUE, catch, overall vessel length, and held and owned quota.

Finally, the effect of operators' connectedness on market functionality (annual quota balance and profit) was also modelled. Quota balance for active operators was the ratio between landings and the number of held quota (owned + bought + leased in – sold – leased out quota) (Innes *et al.* 2014). For investors, this was the ratio between leased out and the sum of owned + bought + leased in – sold quotas. The profit of active operators was calculated by the product of individual catch and the average price paid by processor minus an average total cost per potlift, AU$30 taken from a previous survey (van Putten and Gardner 2010), and an average annual lease quota price (AU$/kg) provided by a quota broker (M. Atkins). As no estimates of transaction costs were available for investors, the revenue from quota leased out was simply the total lease price times the number of held quota.

Models were fitted using Linear Mixed Effect Modelling (LMM) given that the data was organized as panels (Hoff 2003; van Duijn *et al.* 2004; Westveld and Hoff 2011). As the measurements were repeated, operators showed autocorrelation, and as the operators interacted with each other, there was also correlation amongst them. Therefore, fishing seasons and operators were considered as random effects. Interaction between explanatory variables were explored and modelling was carried out using the R package *nlme* (Pinheiro *et al.* 2014).

For each model, a McFadden's pseudo R^2 was calculated, which values ranging between 0.2 and 0.4 are considered to be indicative of very good model fits (Louviere *et al.* 2000). It was showed through simulation that this range of pseudo R^2 is equivalent to a range of 0.7 to 0.9 for a linear function (Domenicich and McFadden 1975).

4.4. Results

Changes of lease quota trade network

The lease quota trade network in TRL fishery had structural variation between the two stock status periods (Fig. 4.1). During the period of stock growth the number of lease trade connections amongst operators increased. There was a trend of increasing network density that extended until the second year of the period of stock decline but with a period of lower network density immediately before the stock declined in 2006. Network density peaked in 2008 when the stock was in rapid decline. Network density slightly increased again in 2011 and 2012 when the stock remained depleted. Given high values of average path length and diameter, the lease quota network appeared to decrease the degree of randomness between the end of the periods of stock growth and the beginning of the stock decline period. For instance, the average path length and diameter of the network remained relatively constant at lower values during almost the entire period of stock growth. Greatest change in these two statistical indicators occurred between 2005 and 2010 with a maximum in 2008. The maximum value of each statistical indicator was reached in the second year of the stock decline period (Fig. 4.1). Biomass and CPUE were still high at this time relative to 2011 and 2012, however the lease quota price was in a downward trend (Fig. 3.1). Thus, the statistical indicators showed significant higher mean values during the period of stock decline (Table 4.2), which is result of the large values during the three first years.

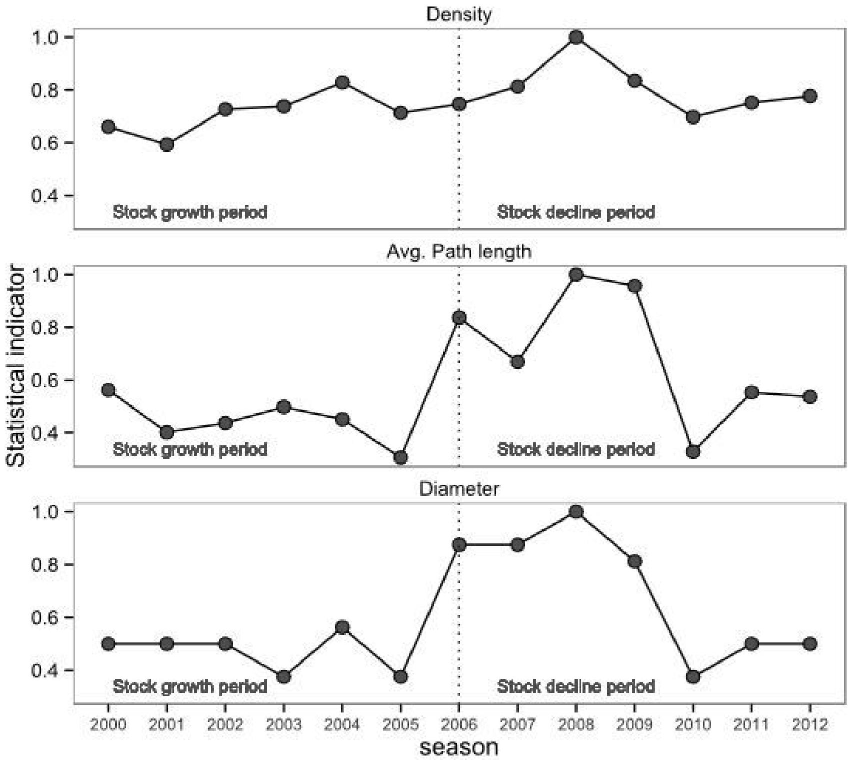


Figure 4.1. Annual averages for network-level statistical indicators. The indicators were standardized by the respective maximum value.

Lease quota price, biomass (total), and CPUE significantly affected the structure of the network while no significant effect was observed for exploitable biomass, mature biomass or recruitment. Values of pseudo R^2 ranged between 0.25 and 0.47 meaning that independent variables in the models explained between 22% and 47% of statistical network indicators.

Table 4.2. Generalized least model outputs from indicators of the quota lease trade network and variables that describe the stock status. Price = lease quota price, Period = contrast between stock growth and decline periods, R^2 = McFadden's pseudo R^2.

Variable		Coefficient		t-value	p-value	R^2
Response	Explanatory	Value	Std. Error			
Density	(Intercept)	0.093	0.267	0.348	0.735	0.474
	Period	-0.310	0.086	-3.600	0.005	
	Biomass	0.958	0.354	2.708	0.022	
Density	(Intercept)	0.659	0.076	8.652	<0.001	0.216
	CPUE	0.200	0.091	2.203	0.050	
Average path length	(Intercept)	-1.169	0.428	-2.731	0.021	0.257
	Period	-0.802	0.140	-5.729	<0.001	
	Biomass	2.496	0.567	4.401	0.001	
Average path length	(Intercept)	-5.835	2.629	-2.220	0.054	-0.273
	Biomass	8.508	3.496	2.434	0.038	
	Price	8.017	2.772	2.893	0.018	
	Biomass x Price	-10.641	3.727	-2.855	0.019	
Diameter	(Intercept)	-7.156	1.935	-3.699	0.005	0.395
	Biomass	10.111	2.490	4.060	0.003	
	Price	8.532	1.829	4.666	0.001	
	Biomass x Price	-11.424	2.454	-4.656	0.001	

Biomass and CPUE positively influenced network density with greatest effect from biomass, as inferred from both pseudo R^2 and regression coefficients (Table 4.2). The interaction between biomass and lease quota price indicated that when both were high the path length and diameter were low. This was apparent from the low values of average path length and diameter during the period of stock growth, when biomass and quota price values were high. Also, both network statistics were low when biomass and quota price were low at the end of the period of stock decline (Fig. 4.1). This interaction also revealed that path length and diameter reached high values when the biomass was declining and the quota price was still relatively high. This scenario was evident during the first three years of the stock declining period.

At an operator (vertex) -level there were also differences between both stock status periods (Fig. 4.2). The annual average of the indicators in-degree, betweenness and eigenvector, showed a downward trend during the first three seasons of the period of stock growth, with a slightly increasing trend in the in-degree and betweenness indices, and a relatively stable pattern in eigenvector values during the rest of the period. The out-degree indicator remained constant during this whole period. Then, in the period of stock decline each indicator reached a peak between 2007 and 2009. The downward trend after the peak reversed in 2011, evident in eigenvector values. These trends reflected initial adjustments of connections (transactions) amongst operators in the lease quota market, and a posterior response to increase and decrease the stock abundance.

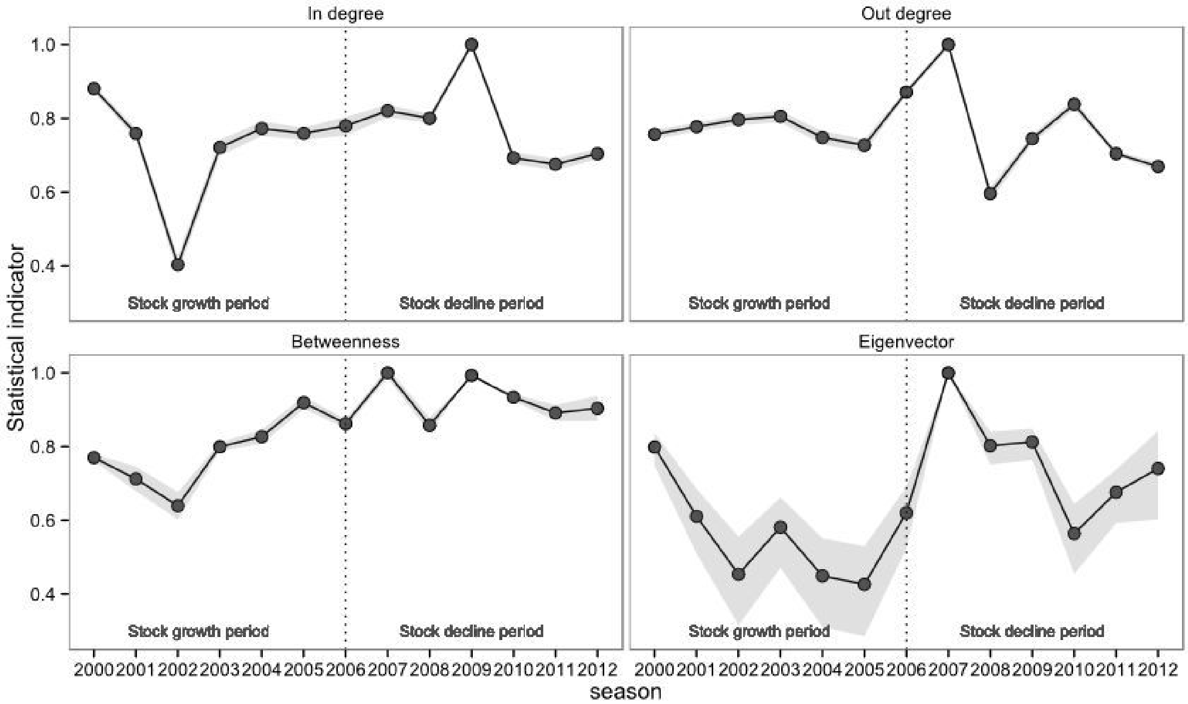


Figure 4.2. Annual averages for statistical indicators at the operator level. The indicators were standardized by the respective maximum value. Shaded zone represent confidence intervals.

Connectedness and market functionality

Connectedness (as measured by trading connections) was influenced by operational characteristics of size (level) of operation and quota ownership (Table 4.3), and in turn, connectedness influenced operators' level of economic achievement (as measured by quota balance and profit) (Table 4.4), which implied market functionality. In general, connectedness for active operators (as defined by the in- and out-degree – or the number of trade connections) was related to the size of their operations; specifically vessel length, and the number of held quotas units interacting with catch (Table 4.3). There was a distinction between the effect of in-degree (leasing quota in) and out-degree (leasing quota out) on the operator's connectedness. The actual level of operation (the product of catch level and held quotas) was high for operators with a high number of leasing-in connections (in-degree) and *vice versa* for operators with a high number of leasing-out connections (out-degree).

Another aspect of connectedness of operators was whether they were well-connected to other well connected operators (as measured by the eigenvector). The operator's eigenvectors were affected by the level of catch and the quota ownership (as opposed to quota fished). More active operators, with a high level of catch, tended to be less connected with other well-connected operators (indicated by the negative sign on the coefficient in Table 4.3). In contrast when operators had a higher level of quota ownership they were connected with well-connected operators. For investors, the eigenvector was the only network dimension that could be modelled. The investor's connectedness (as measured by the eigenvector) was positively influenced when quota ownership was high but was negatively affected when the number of untraded quota units (held quotas) was high.

Table 4.3. Linear mixed model outputs that described the relation between statistical network indicators that describe the operators' connectedness and variables that describe the operators' level of activity and ownership. R^2 = McFadden's pseudo R^2.

Operator typology	Variable		Coefficient		t-value	p-value	R^2
	Response	Explanatory	Value	Std. Error			
Active operator	In-degree	(Intercept)	1.349	0.284	4.754	<0.001	0.303
		Vessel length	0.061	0.016	3.749	<0.001	
		Catch	0.007	0.004	1.690	0.091	
		Held quotas	0.012	0.033	0.371	0.711	
		Catch x Held quotas	0.315	0.020	15.631	<0.001	
	Out-degree	(Intercept)	3.459	0.377	9.182	<0.001	0.355
		Vessel length	0.159	0.021	7.545	<0.001	
		Catch	-0.008	0.006	-1.539	0.124	
		Held quotas	-0.036	0.043	-0.830	0.407	
		Catch x Held quotas	-0.145	0.026	-5.564	<0.001	
	Eigenvector	(Intercept)	0.566	0.082	6.931	<0.001	0.332
		Catch	-0.025	0.013	-1.967	0.049	
		Owned quotas	0.020	0.008	2.367	0.018	
Investor	Eigenvector	(Intercept)	0.057	0.008	6.931	<0.001	0.248
		Owned quotas	0.002	0.001	2.367	0.018	
		Held quotas	-0.003	0.001	-1.967	0.049	

Looking at the lease trade connections in another way, the network statistics that are a measure of operators and investors connectedness can also be used to explain their profitability and quota balance, which in turn is measure of market functionality. The quota balance and profit for active operators was positively affected by a high in-degree (leasing quota units in), but the profit was reduced where there was a high out-degree (leasing quota units out) (Table 4.4). In addition, when active operators were connected with well-connected operators (eigenvector) their quota balance and profit was reduced. Conversely, investors increased their quota balance and revenue when they were connected with well-connected operators (indicated by the positive sign on the coefficient for the eigenvector).

Table 4.4. Linear mixed model outputs that described the relation between statistical network indicators that describe the operators' connectedness and variables that describe the operators' annual level of success in the fishery (and profit). R^2 = McFadden's pseudo R^2.

Operator typology	Variable		Coefficient		t-value	p-value	R^2
	Response	Explanatory	Value	Std. Error			
Active operators	Quota balance	(Intercept)	0.570	0.114	4.984	0.570	0.462
		In-degree	0.177	0.017	10.692	0.177	
		Out-degree	-0.040	0.014	-2.930	-0.040	
		Eigenvector	-1.343	0.480	-2.799	-1.343	
	Profit	(Intercept)	16.697	8.974	1.861	0.063	0.397
		In-degree	14.388	0.842	17.078	<0.001	
		Out-degree	-15.564	0.698	-2.229	0.026	
		Eigenvector	-75.829	24.515	-3.093	0.002	
Investors	Quota balance	(Intercept)	0.515	0.022	23.200	<0.001	0.413
		Eigenvector	0.582	0.105	5.537	<0.001	
	Revenue	(Intercept)	62.587	5.081	12.318	<0.001	0.386
		Eigenvector	34.548	11.730	2.945	0.003	

Connectedness indicators explained between 39% and 46% the variability of indicator of market functionality (quota balance and profit). Betweenness was also evaluated, but this did not show significant influence on any market functionality indicator, and neither did any of the possible interactions.

4.5. Discussion

The economic outcomes of ITQ systems occur through fleet rationalization and market-based rewards when stock are managed conservatively (Grafton *et al.* 2000; Costello *et al.* 2008; Kompas *et al.* 2009, 2011). Fundamental to these potential economic benefits is an effective and functional quota market that facilitates permanent and temporary (lease) quota transfer amongst operators. Market functionality may be influenced by operators' trade connections (Innes *et al.* 2014), which in turn are influenced by operational characteristics of the operators. The results of this research show that lease quota trading activity increased in the lease quota market during a period of stock growth, but trading activities continued to grow until two years after the stock started to decline.

Changes observed in the structure of the quota lease trade network were related to stock biomass and CPUE. The number of connections amongst operators increased while biomass and CPUE also increased and *vice versa*. Stock rebuilding seemed to create an expectation of future catch increase and reduced operators' perception of uncertainties associated with fishing. During the period of biomass increase, operators who depended on leasing in quota units increased their number of trade connections. Following the same rationale, a reduction of connections would be expected when stock biomass declined although this did not occur until two years after the biomass and CPUE began to decline. This may have been because operators' did not interpret the commencement of decline as a signal of substantial reversal in stock rebuilding. It is also possible that the fact that the TAC was still readily caught was critical. This finding of a delay in behavioural change is not unusual and it has been observed elsewhere that resource scarcity does not always act as a driver of change in operators connections in a network (Ramirez-Sanchez and Pinkerton 2009). However, in the current case the delay between changes in stock abundance and changes in the lease quota trade network seemed to be related to the way operators perceived fishing uncertainty. For instance, despite the ability of operators to readily observe decline in catch rates, their downward adjustment in trading was delayed to the time when the TAC was not entirely caught in 2009, which was reflected in decreasing statistical network indicators.

Lease quota trade network randomness was also influenced by the lease quota price, with a significant statistical relationship with average path length and network diameter. These two indicators started to increase at the time when the quota price started to decrease. The quota price is critical information for trading by operators and should reflect the stock status (Arnason 1990; Batstone and Sharp 2003; Newell *et al.* 2005). The reduction of randomness, given higher values of average path length and diameter (Watts and Strogatz 1998) seemed to be related with the operators' decisions on quota leasing and affected by the operators' financial capacity. Operators with an apparent lower capacity to negotiate a lease price that lead to a higher profit (lower bargaining power), had access to quota units at lower price than would occur in conditions of higher competitiveness. A similar result was shown for the TRFL when the quota transfer rate amongst operators with different financial capacity was analysed (León *et al.* 2015). This increase in activity of a specific group within the network is consistent with the increase in average path length and diameter that indicated reduced randomness. The apparent effect of declining stock on increase of activity and number of connections of operators who usually had a lower profile was consistent with high eigenvector values. Eigenvectors are connectedness indicators that respond to the number of connections with well-connected operators and these increased when the lease quota price decreased. This trend of increasing connections for smaller trading operators in a less competitive market was consistent with observations elsewhere, in that unequal bargaining power is an issue predicted and evident in many fisheries (NRC 1999; Pinkerton and Edwards 2009). The number of connections eventually plateaued as stock continued to decline, suggesting that active operators began to respond more to higher costs from a low CPUE after two consecutive years of a non-limiting TAC. Thus, greater access to well-connected operators in the lease quota market no longer facilitated increase in trades.

It is important to note that along with operators' fishing level there are other factors that also may explain part of the variance for statistical network indicators, such as number of pots, engine power, and skipper experience. Similarly, the variance of success in the fishery (quota balance and profit) may also be explained by other factors. For example, acquaintance relation amongst operators (Frusher *et al.* 2003), use of brokers (van Putten et al. 2011; Schnettler 2009), participation of processors in the market (van Putten *et al.* 2011) fishing efficiency (Little *et al.* 2009) and, financial capacity and debts (Squires *et al.* 1995). Low variation in the market functionality indicators explained by the statistical network indicators as seen here is not unusual with similar results obtained when modelling centrality metrics from a network of information flow and fishing success (Turner *et al.* 2014). Nonetheless, the results showed that connectedness was influenced by the level of fishing activity and in turn the connectedness influenced the indicator of success in the fishery that informed about market functionality.

Quota balance and profit were lower when active operators had higher levels of connections with well-connected operators. This suggests that well-connected operators had bargaining power with many alternative operators to lease their quota to. Operators with a high number of connections to other well-connected operators were also those with higher financial capacity and thus greater bargaining power. This situation has been observed when processors become involved in the quota market to secure fish delivery and use their financial capacity to improve their bargaining position (Pinkerton and Edwards 2009). This was consistent with high quota balance and revenues for investors when they showed a high number of links with well-connected operators.

This study exemplified the importance of monitoring the lease market in an ITQ managed fishery, given that changes in the stock size were reflected in the connectedness of operators' trade dynamic. The findings revelled some degree of power asymmetry, which may be accounted by managers; thus effectivity of measure to avoid concertation may be regularly reviewed, especially when biomass changes happen.

4.6. Conclusions

The dynamic and structure of the lease quota trade network changed in response to stock abundance that occurred as a result of the interplay between TAC settings and recruitment fluctuation (Linnane, et al. 2010). As stock began to decline, operators presumably retained expectations of ongoing high catch rates and responded by participating in markets, which lead to increase in connections and thus the complexity of the lease quota trade network. As catch rates fell further, operators with a presumably lower bargaining power responded to decrease in the lease quota price by increasing their connections in the network, taking advantage of a less competitive market. At the extreme the TAC became non-limiting and financial capacity became the primary driver of these operators' behaviour.

Connectedness that operators developed in the trade network depended on their level of fishing activity. Highly active operators developed more numerous trade linkages, acquiring high levels of quota and profit. Operators with low levels of fishing activity and high levels of quota ownership, as well as investors with high levels of quota ownership, were able to develop connections with well-connected operators. This meant that when operators had high financial capacity they more actively traded quota. Market functionality was influenced by connectedness, and this this was larger when active operators had higher quota balance and profit. This occurred when operators were highly connected with other operators; however, quota balance and profit was lower when they were linked with well-connected operators. These well connected individuals appeared to have a high level of financial capacity and bargaining power as they affected trades for a large number of quota units.

This research shows that operators respond differently to temporal changes in stock recruitment and productivity, where their business structure, financial and bargaining capacity were the main drivers. These findings give some insight to managers about the power asymmetry happening in the lease market, especially at the extreme biomass changes, when the effects of a non-limiting catch become critical, and the operator's behaviour changes are more evident.

Chapter 5

Experimental analysis of coordination of fishing effort to reduce dissipation of economic rent in stock enhancement

5.1. Abstract

Individual Transferable Quota (ITQ) systems have been used to control harvests and increase fisheries' economic efficiency; however, they do not eliminate competitive fishing which can result in stock and congestion externalities that are especially apparent when resources are spatial heterogeneous. These externalities arise because ITQ systems do not control the spatial distribution of effort leaving fishers to concentrate their effort in more profitable patches. The potential for cooperative behaviour to be used to reduce this congestion was explored using an experimental economics approach in the context of management of a stock enhancement program (SEP). Four treatments were applied involving different systems which were: a combination of compulsory, voluntary and by-use payment for the SEP, with either open or exclusive access to the enhanced zone (EZ). Income is either given directly to individuals or split between participants through income-sharing (as occurs in cooperatives). Voluntary payment to fund the SEP enabled individuals to opt out of cooperation, which reduced the enhancement activity and led to a significantly lower cooperation than the optimal level and also lower relative to the compulsory payment system. Treatments that included a by-use payment combined with exclusive access to the EZ were most effective in preventing dissipation of economic rent. The different rule settings were affected by participants' expectations of reciprocity, with greater involvement and thus production from the SEP amongst cooperative participants. Perceptions of vulnerability were also important, as more self-interested participants were more likely to exclude themselves from the SEP. The structure of rules may

enable individuals who are more intrinsically cooperative to drive the fishery towards a state with low rent dissipation.

Key words: *Cooperation, trust and reciprocity, translocation, quota system, fisheries management.*

5.2. Introduction

Individual Transferable Quota (ITQ) systems have successfully reduced the so-called "race-to-fish" problem. Given secure and tradeable access to a fraction of the Total allowable catch (TAC), fishers have less need to compete for fish so issues such as over-capitalization, shortened fishing seasons and lowered quality of products tend to be reduced (Grafton *et al.* 2000; Costello *et al.* 2008). However, inefficiency and rent dissipation may arise nonetheless where some aspect of spatial stock heterogeneity creates an incentive to compete. Stocks commonly have patchy distributions and are heterogeneous in terms of quality of products (size, consistency of flesh, presence of parasites, coloration differences, etc.), productivity, and accessibility (depth and proximity to ports), which ultimately manifest as economic heterogeneity (Sanchirico and Wilen 1999). Under these conditions, assignment problems may emerge resulting in an inefficient use of resources (Ostrom *et al.* 1994).

Whether ITQs do not delineate where fishers may harvest their quotas theory predicts that fishers will focus their fishing effort on the most profitable patches (Copes 1986; Boyce 1992). This will dissipate rent if fishers excessively deplete higher value or more productive patches. These patches are analogous to an open access fishing ground within the larger ITQ controlled fishery. Stock heterogeneity may also produce congestion externalities, where fishers have an incentive to achieve higher catch rates by fishing premium areas before others, leading to competition, gear interference, and possible loss of product quality (Costello and Deacon 2007; Holland 2011; Huang and Smith 2014). Hence, although ITQs may reduce rent dissipation, they do not eliminate it, because fishers continue to act for their individual rather than their collective interest. This means that incentives to coordinate harvests or other aspects of cooperation have potential to increase economic yields even where ITQs are present.

There have been several attempts to address management problems derived from spatial heterogeneity of stock through coordination of fishing effort. For example, in the New England groundfish fishery, the central authority allowed permit holders to form voluntary ‘sectors’ (e.g. groups of different fishing gear operators) and receive catch allocations for individual species. The sectors were able to manage the level of effort, resulting in increasing economic gains (Holland and Wiersma 2010). Similarly, fishers in region three of the New Zealand abalone (Paua) fishery coordinated fishing efforts to reduce competition in highly accessible zones, resulting in higher catch rates across the whole zone (Costello and Deacon 2007; Deacon and Costello 2008; Deacon 2012). Another approach used to address the stock and congestion externalities has been through arrangements involving pooling of revenues, reduction of costs and distribution of profits amongst all operators (Uchida and Baba 2008; Uchida and Watanobe 2008). Pooling arrangements can be jointly employed with fishing effort coordination leading to significantly higher economic (Uchida 2010).

This type of interactions amongst fishers, coordination and cooperation, harvesting and stock enhancement decisions can be analysed with game theory and experimental economics to explore issues for management of common pool resources (Ostrom *et al.* 1994). This enables stakeholders' behaviour to be assessed to guide managers on likely outcomes and necessary incentives when designing management systems (Cárdenas *et al.* 2013). Economic experiments are similar as many scientific experiments where systems are simplified, sacrificing some degree of accuracy to enable general principles to be understood. The rationales undelaying experimental economics is that when management tools are set in an experimental design would influence human behaviour at a basic biological and psychological level representative of the real world (Kraak 2011). Thus experimental outcomes are generalizable to fisheries rather than a specific fishery at one point in time. Experimental economics thus provide a tool to explore regulations that promote willingness to support translocation or other forms of enhancement and cooperation amongst fishers.

In the Tasmanian rock lobster fishery (TRLF), the effort shifted inshore due to higher demand and price for darker red, higher value lobsters that occur in shallower water (Ford 2001; Bradshaw 2004). Even though that the fishery is ITQ managed, competition between fishers continued to the point that shallow water areas became depleted while deep areas were underexploited (Semmens *et al.* 2006). To deal with this issue and based on economic and biological feasibility (Gardner and Van Putten 2008a,b), the Tasmanian commercial industry translocated lobsters from deep to shallow areas to improve market characteristics and growth (Gardner *et al.* 2015b). This was thus a form of stock enhancement that required payment by fishers to increase production so that profits and quota capitalization increased (Green *et al.* 2012).

The commercial scale translocation operations were financed entirely by the rock lobster industry; however, some members were resistant to paying for it despite a high return on investment (cost was $3 / extra kg of quota allocated, which the quota owner could then lease for around $24 / kg; Gardner *et al.* 2015b). Despite debate, the decision to carry out translocation proceeded through a voting process that led to compulsory participation by all fishers. This did not involve intervention by the Government authority and there is some evidence that intervention weakens willingness to cooperate and reduces stewardship (Bowles 2008; Richter and van Soest 2011). An alternative approach could have been voluntary payment without any access restriction to provide exclusivity to the higher quota allocation that enhancement allowed, although the concern was that this would promote free riders. Voluntary participation can have benefits however, with evidence that it increases the sense of ownership amongst fishers and increases compliance with regulations (Hatcher *et al.* 2000; Nielsen 2003; Nielsen and Mathiesen 2003).

Therefore, an economic experiment was conducted here, motivated by and loosely structured around commercial rock lobster translocation operations described above, to assess management measures that require high level of coordination. These measures included both restricted and unrestricted access treatments to the enhanced zone. Additionally, cooperatives were included as a treatment in the experimental design with the expectation that they would promote cooperation and stewardship (Deacon 2012) and enable members to develop their own regulation (Uchida and Baba 2008; Uchida and Watanobe 2008). Based on this history, the following hypotheses were formulated: (i) voluntary payment of the translocations would promote more cooperation and reciprocity than compulsory payment; (ii) exclusive and secure access to the enhanced zone would promote more cooperation and reciprocity than when access security is weak; and (iii) having collective profits would result in the highest level of cooperation and reciprocity leading to highest economic yield.

5.3. Methods

Experimental design

The experiment was designed in the context of an ITQ managed fishery, but quota transfers was not accounted to simplify the design. Terminology and the context was explained to participants in the overview section of instruction provided before running each experimental session (Appendix 5.2). The experimental design set up to examine fishers' motivation for coordination and ability to reach an optimal fishing effort allocation in a fishery with spatial stock heterogeneity and enhancement. The general framework was a stock enhancement program (SEP) that considered restocking a specific zone to address stock heterogeneity by translocating RL from other zones. As a result of the translocation there were two zones (*i*) an *enhanced zone*

(EZ) with potentially higher profitability relative to (*ii*) a *non-enhanced zone* (N-EZ). Three factors were considered in the experiment. The first factor was the system for *Payment* of the cost of the SEP with three levels applied: (*i*) *compulsory payment*, where every participant had to pay for the program; (*ii*) *voluntary payment*, where participants chose to pay or not, regardless whether they fished their quotas in the EZ; and (*iii*) *payment by-use*, where fishers had to pay only if they were going to fish in the EZ. The second factor was *harvesting-strategy* and had two levels applied: (*i*) *individual harvesting*, as in an individual quota (IQ) management system; and (*ii*) *collective harvesting*, as in a community-based management system, with pooling of costs and revenue so that profits were shared equally amongst only those operators that form part of the collective with exclusive access to the EZ. Finally, the factor of *access* was applied with two levels: (*i*) *access restriction* where fishing in the EZ was controlled; and (*ii*) *no access restriction* to the EZ. Combinations of levels of these three factors were referred as treatments, which represented different co-management strategies, and were labelled according the type of payment. Hereinafter referred to as treatments *Compulsory*, *Voluntary*, *By-use A* and *By-use B* (Table 5.1).

Table 5.1. Combination of treatments in the experimental design.

Treatment label	Factors			Participants decision
	Payment	Harvesting	Access restriction	
Compulsory	Compulsory	Individual	No	Where to go fishing
Voluntary	Voluntary	Individual	No	Pay for enhancement/ Where to go fishing
By-use A	By use	Individual	Yes†/No	Pay for enhancement/ Where to go fishing
By-use B	By use	Individual/Collective‡	Yes†/No	Pay for enhancement/ Where to go fishing

†Access to the enhanced zone (EZ) was restricted when participants choose not to pay for the stock enhancement program (SEP).
‡Collective harvesting occurred for those participants who chose to pay for the SEP, implying membership of a cooperative that exploits the EZ.

The experimental fishery operated under an Individual Quota system (IQ) where the Total Allowable Catch (TAC) was divided into 24 quota units evenly allocated amongst eight participants per experimental session. Hence each participant was allocated a quota holding of three units that could be fished in one or both zones according to the participants' decision, which was made at the beginning of every fishing season (or round), in each experimental session. Participants were allowed to communicate with each other before making their decisions, as cooperative actions can emerge from bargaining (Nash 1951). Participants thus made decisions within the bounds of the experimental factors (Table 5.1) and with reference to an expected payoff outcome, based on Cardenas (2000) (Appendix 5.1). This allowed participants to estimate their payoff based on their own decisions including agreements with other participants, whether they were to contribute to the SEP, and to the zone in which they would fish their quota units. The payoff was higher with more participants contributing to the SEP, provided they coordinated their fishing effort and allocated their quota optimally across both zones.

The maximum economic yield from the fishery was obtained if: (i) all participants contributed to the SEP; and (ii) catch was spread with 14 units in the EZ and 10 in the N-EZ. This distribution of quota units led to unequal payoffs for each participant unless they took turns in reducing their catch from the more profitable EZ (this occurred when two of the eight participants allocated one of their three quota units into the EZ and two in the N-EZ, while the other six participants allocated two units in the EZ and one in the N-EZ). Individual participants could increase their payoff in any one round by putting more of their effort into the EZ but this would deplete the zone so that overall economic yield was reduced in the next fishing season. Consequently, any deviation from the optimal scenario implied that one or more participants were choosing to not act in the interest of the whole group and not maximise the economic yield from the fishery. This behaviour was taken as participants following their Nash equilibrium strategies to maximize their individual payoff under the risk that others could also follow the same strategy (Nash 1950, 1951). These deviations could occur when participants decided to not cooperate and contribute to the SEP; or when they broke agreements around coordination of fishing effort so that there was a sub-optimal allocation of effort in one of the two zones (in terms of overall economic yield).

Experimental procedures

Experimental sessions were carried out in the University of Tasmania's experimental computer laboratory between February and March 2013. For each treatment, four independent sessions and 20 rounds per session were run. Each session lasted around 90 minutes, including the initial time to read instructions (Appendix 5.2) and complete a multiple-choice quiz (Appendix 5.3) to ensure that all participants understood the instructions. The experiment did not start until the participants were able to correctly answer the quiz. Upon completion of the experimental session participants were confidentially given cash payments based on the amount earned through the simulated fishery. Payments ranged from AUD$27 to AUD$45 (AUD$30 average), which included a participation payment of AUD$10. The supplementary material includes an example of the instructions and the respective quiz supplied to participants before the start of the experiment. The experimental treatments were programmed in custom-designed software. Participants were allowed to communicate with each other during the experiments using the built-in anonymous chat in the experimental software, verbal communication was prohibited. Record keeping involved non-disclosure of identity to ensure anonymity.

Experimental participants

Participants were recruited from students across the University of Tasmania campus who were invited to be part of a pool of experimental subjects. Eight individuals were randomly drawn from this pool for participation in each session. Using students for economic experiments has been focus of research to examine biases and external validity. The main concerns have been (*i*) the students' behaviour may not represent the real actors' behaviour in the real world (Levitt and List 2007; Falk *et al.* 2013); and (*ii*) self-selection, where students showing more pro-social preferences are more prone to volunteer, introducing a bias toward to common-interest outcomes (Murphy et al. 2003; Levitt & List 2012). The first of these biases is important for experiments where specific operational knowledge is required. However, the rapid training session and highly stylised fishery were aimed at safeguarding against this bias. Optimal outcomes were not achieved by knowledge of fishing practices but by coordination with other participants instead. The experiment was thus focussed on a general human response, and students have been found to not deploy a significantly different behaviour than the general population, for example, in trust experiments (Exadaktylos et al. 2013).

Regarding concerns of a self-selection bias, it has been shown that students who have participated in economic experiments do not show significantly more pro-social responses than students who have never participated; and those with pro-social inclinations are neither more likely to participate in experiments nor participate more frequently (Cleave *et al.* 2010; Falk *et al.* 2013). Similar results have been found in experiments with non-student participants, where volunteers do not significantly behave more pro-socially than non-volunteers (Bellemare and Kröger 2007; Anderson *et al.* 2013).

Finally, it should be noted that this experiment was not designed to measure the actual quantitative level of self or common-interest behaviour treatments' setting may lead to. The intent of this research was to classify directions rather than magnitude and the influence of different rules on participants' behaviour. This ability to qualitatively examine responses is considered one benefit of the laboratory experiment (Levitt and List 2007) although it is important to be cognisant of limitations when applying conclusions to real fisheries. For example León et al. (in press) show that expected stewardship behaviour of fishers in real ITQ fisheries can fail in the presence of numerous unique factors.

Statistical methods

A Nash Decision Index (NDI) was calculated and compared across the treatments to assess the effectiveness of the overall cooperation and coordination to optimally allocate fishing effort and reduce economic rent dissipation (*Nash behaviour*). The NDI was the ratio between actual total profit and optimal total profit per round. Additionally, to better understand the participants' behaviour reflected in the NDI, the number of participants paying for the SEP was compared across the different management structures to assess whether these provided sufficient incentives to initiate willingness to pay costs (*willingness to pay*).

The extent to which participants showed either reciprocity or broke the agreed coordination of fishing effort was assessed across treatments (*Trust and reciprocity model*). To exercise trust and reciprocity participants should have agreed and undertaken turns in allocating only one quota unit in the EZ. Depending on how many participants paid for the SEP, there was an optimal average number of quotas per participants to be fished in the EZ to reach the optimal economic yield. This optimal number of quotas was calculated for each treatment from the payoff table according to the number of participants who paid for the SEP (Appendix 5.4).To assess trust and reciprocity, the actual average number of units fished in the EZ was contrasted against these optimal numbers across the four treatments.

To evaluate whether participants changed their behaviour through the 20 fishing seasons (rounds) of each session, the whole period of the sessions was split into three phases and the first and third were contrasted, relative to the variables described above: NDI; number of participants who paid for the SEP; and the index of trust and reciprocity based on distribution of quota units between zones.

Analyses were conducted with three generalised estimating equation (GEE) models as described in (Emery *et al.* 2015). The modelling was performed using R (R Core Team 2014) and the R package geepack (Højsgaard *et al.* 2006). The GEE modelling is suitable for longitudinal or panel data, which involves observations of multiple subjects' outputs through time, which is often autocorrelated (Liang and Zeger 1986; Zeger and Liang 1986; Ballinger 2004). The GEE approach resolves this by estimating a coefficient to describe changes in the population mean (rounds), given changes in the covariates, rather than changes in the individual (participants) mean as occurs with Mixed models (Hubbard *et al.* 2010). In order to obtain a better estimate of the variance, and efficient and unbiased estimations of coefficients, a working correlation structure is provided to address within population non-independence from correlation amongst participants (Diggle *et al.* 2002). A key strength of the GEE approach is that even if the working correlation structure is miss-specified, GEE provides robust estimations (Liang and Zeger 1986; Freedman 2006; Lai and Small 2007; Lalonde *et al.* 2013). Additionally, the GEE aproach is robust to non-normally distributed response variables (Harrison and Hulin 1989).

Fitting a GEE model involves three steps (Ballinger 2004; Zuur *et al.* 2009): (*i*) specifying the systematic component and the link transformation function that relates the conditional mean and the systematic component (McCullagh and Nelder); (*ii*) specifying the response variable distribution, thus the variance may be calculated as a function of the mean response (Hardin and Hilbe 2003); and (*iii*) specifying the correlation structure of the responses amongst subjects nested within groups (rounds) (Liang and Zeger 1986). Covariates included in the NDI model here were *treatment*, *session phase*, *payoff* in the EZ and *cumulative income*. An interaction term *treatment x session phase* was included to determine whether participants changed their behaviour during sessions relative to both treatment and period of time. The log-link transformation function was used in each case; the gamma distribution was used for the NDI model and Poisson for the contribution and reciprocity models. First order autoregressive structure (AR-1) was used as a working correlation because the participants' behaviour was measured though time and the models fitted with this correlation structure showed the lowest Pan's quasi-likelihood under the independence model information criterion (QIC) score (Pan 2001; Pan and Connett 2002). QIC was estimated using the R package *QICpack* (Hocking 2014).

5.4. Results

Rent dissipation

The results of the *Nash decision index (NDI) model* showed that at the end of experimental sessions the user-pay systems for access to the EZ (treatments *By-use A* and *B*) had lower rent dissipation, with a significantly lower NDI, relative to the treatments *Compulsory* and *Voluntary* (Fig. 5.1, Table 5.2). The *Voluntary* treatment had a significantly higher NDI, and the highest rent dissipation. In other words, this treatment gave rise to self-interest rather than common-interest behaviour amongst participants. During the first 6 session of the total 20 experimental sessions, rent dissipation in the *By-use A* and *B* treatments were not significantly different to the treatment *Compulsory* (p=0.999 and p=0.978 respectively, Fig. 5.1 and Table 5.2). This meant that non-exclusive access to the EZ did not increase rent dissipation when it was combined with compulsory payment, in contrast to when non-exclusive access was combined with voluntary payment (p<0.001, contrast between *Compulsory* and *Voluntary*).

The treatments *Compulsory* and *Voluntary* did not promote improvements in coordination of the distribution of fishing effort by participants' while rounds were progressing, with no significant differences in the NDI between the first and last third of sessions (*p*=0.878 and *p*=0.760, respectively). Conversely, rent dissipation progressively reduced with successive fishing seasons or rounds in the treatments *By-use A* and *B*. This was apparent because the NDI was significantly lower at the end of the session for both treatments (*p*=0.012 and *p*=0.002 respectively). These two treatments did not have significantly different NDI throughout the experimental sessions (*p*=0.994 and *p*=0.772, contrast between the first and last third of sessions respectively). This meant that under the current design, the profit pooling arrangement did not significantly improve the NDI compared to the system of exclusive access to the EZ with enhancement with by-use payments.

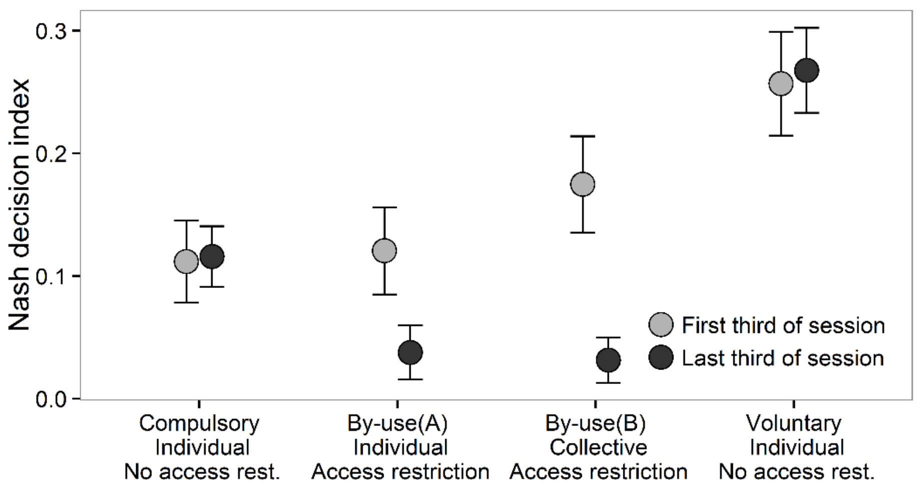


Figure 5.1. Nash decision index across treatments during the first and last third of the experimental sessions (first and last six rounds respectively). Higher Nash decision index implies more self-interested decision making and higher rent dissipation. Bars represent the 95% confidence intervals.

Table 5.2. Pairwise contrast to assess differences in the Nash decision index amongst treatments during the first and last third of the experimental sessions (first and last six rounds respectively).

Third of session	Treatment contrast	Estimate difference	Std. Error	z value	Pr(>|z|)
First	*Compulsory vs. Voluntary*	0.116	0.027	4.36	<0.001
	Compulsory vs. By-use A	0.004	0.024	0.15	0.999
	Compulsory vs. By-use B	0.011	0.028	0.4	0.978
	Voluntary vs. By-use A	-0.112	0.027	-4.11	<0.001
	Voluntary vs. By-use B	-0.105	0.030	-3.54	0.002
	By-use A vs. By-use B	0.007	0.028	0.26	0.994
Last	*Compulsory vs. Voluntary*	0.128	0.021	6.05	<0.001
	Compulsory vs. By-use A	-0.064	0.017	-3.83	<0.001
	Compulsory vs. By-use B	-0.077	0.015	-5.13	<0.001
	Voluntary vs. By-use A	-0.191	0.021	-9.24	<0.001
	Voluntary vs. By-use B	-0.205	0.020	10.52	<0.001
	By-use A vs. By-use B	-0.014	0.014	-0.95	0.772

Willingness to pay

Participants decisions whether to pay for the SEP were based primarily on the payoffs; however, decisions were also modulated by regulations included in each treatment. Despite highest payoffs occurring when all participants paid for the SEP, there were significant differences amongst treatments in the number of participants that opted to pay (Fig. 5.2, Table 5.3). The treatment *Voluntary* led to a significantly lower number of participants paying for the SEP in contrast with the treatments *By-use A* and *B*, and this pattern did not change as the sessions progressed (contrast between first and last third of sessions for both treatment respectively, Table 5.3). The treatment *By-use A* and *B* did not show significant differences in the number of participants paying for the SEP at any time of the sessions (Table 5.3). Also, under treatment *By-use B*, participants reacted to other participants behaviour through the rounds and their willingness to pay for the SEP significantly increased (p=0.004, contrast between the first and last third of sessions).

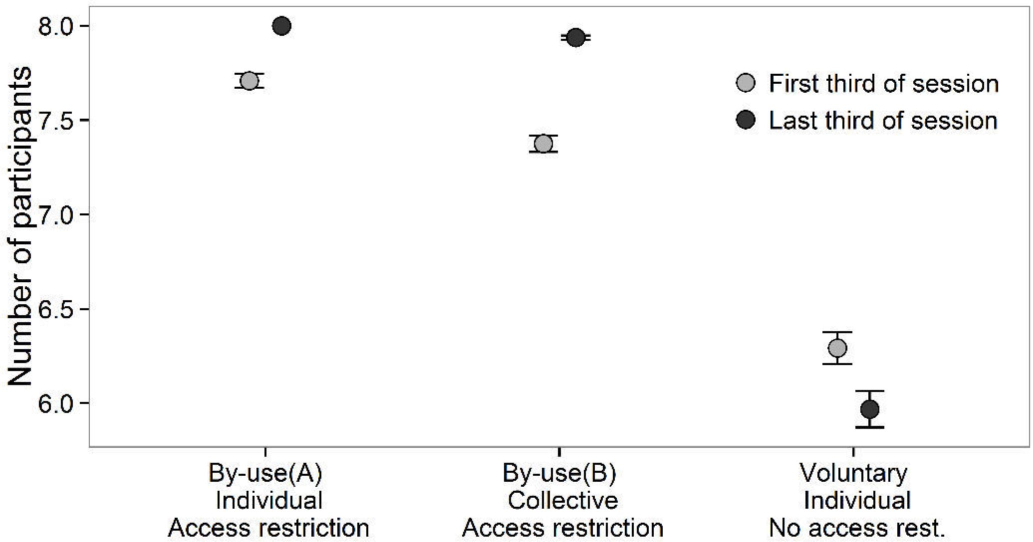


Figure 5.2. Number of participants paying for the stock enhancement program (willingness to pay) for voluntary and by-use treatments, during the first and last third of the experimental sessions (first and last six rounds respectively). Bars represent the 95% confidence

Table 5.3. Pairwise contrast to assess difference in the number of participants paying for the stock enhancement program amongst treatments, in the first and last third of the experimental sessions (first and last six rounds respectively).

Third of session	Treatment contrast	Estimate difference	Std. Error	z value	Pr(>|z|)
First	*Voluntary vs. By-use A*	-0.203	0.047	-4.35	<0.001
	Voluntary vs. By-use B	-0.159	0.048	-3.32	0.003
	By-use A vs. By-use B	-0.044	0.030	-1.49	0.287
Last	*Voluntary vs. By-use A*	-0.293	0.049	-5.93	<0.001
	Voluntary vs. By-use B	-0.285	0.050	-5.74	<0.001
	By-use A vs. By-use B	-0.008	0.005	-1.45	0.280

Trust and reciprocity

In general terms, the treatments *Compulsory* and *Voluntary* did not lead participants to reach the optimal level of trust and reciprocity, with the average number of quota units fished in the EZ significantly higher than the optimal 1.75 units throughout the experimental sessions in both cases, meaning the zone became depleted (Fig. 5.3, Table 5.4). In contrast the treatments *By-Use A* and *B* resulted in the number of quota units fished in the EZ being in the optimal range of these two treatments (Fig. 5.3).

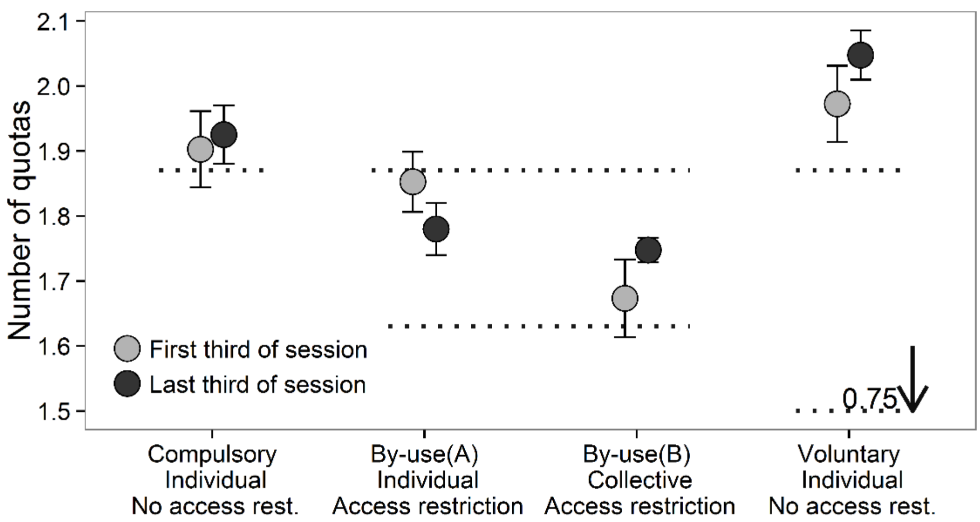


Figure 5.3. Average number of quota units fished in the enhanced zone during the first and last third of the experimental sessions (first and last six rounds respectively). Dotted line represents the optimal number of quota units to be fished under each treatment (Compulsory: 1.75, *By-use A* and *B*: 1.75-1.80 and Voluntary: 1.50-1.75 units). Bars represent the 95% confidence intervals.

Table 5.4. Contrast of actual quota units fished against the optimal number of quota units (1.9) to be fished in the enhanced zone for the first and last third of the experimental sessions (first and last six rounds respectively).

Third of session	treat	Predicted value	Difference	Std. Error	z value	Pr(>lzl)
First	*Compulsory*	1.90	0.153	0.030	5.11	<0.001
	Voluntary	1.97	0.223	0.030	7.44	<0.001
	By-use A	1.85	0.053	0.024	2.23	0.013
	By-use B	1.67	-0.077	0.030	2.51	0.006
Last	*Compulsory*	1.93	0.175	0.023	7.66	<0.001
	Voluntary	2.05	0.298	0.019	15.41	<0.001
	By-use A	1.87	-0.020	0.020	0.98	0.164
	By-use B	1.75	-0.002	0.010	0.26	0.399

5.5. Discussion

Individual Transferable Quota (ITQ) systems have shown to reduce competition amongst fishers and have other desirable effects such as reducing over-capitalization. However, they do not necessarily resolve stock and congestion externalities that result from spatial stock heterogeneity (Boyce 1992). Coordination of fishing effort (Deacon and Costello 2008) and full delineation of quota allocation (e.g. assigning rights to cooperatives) (Deacon *et al.* 2008) have been suggested as mechanisms to overcome rent dissipation that may arise from heterogeneous stocks. Both mechanisms demand a great deal of trust and reciprocity by fishers if they are to succeed because they require cooperation (Fehr *et al.* 2002).

Trust and reciprocity is required, because in social or economic exchanges not all aspects can be controlled with rules, consequently there is usually room for cheating.

In this context, voluntary co-operators (or strong reciprocators) and conditional co-operators (or reciprocal altruists) arise. The first are those individuals willing to reward others for cooperation or punish them when not cooperative, even if this implies a cost. In contrast, the second are self-interested individuals who only will reward and punish if there is a reward (Gintis 2000a; Fischbacher et al. 2001; Gintis et al. 2001; Fehr et al. 2002; Fehr & Fischbacher 2003). The influence of these two kinds of individual depends on the environmental conditions (rules) that influence social or economic exchanges (Fehr *et al.* 2002; Fehr and Fischbacher 2003). In this study was found that participants were highly willing to coordinate fishing effort, reducing rent dissipation, when they had the option of voluntary payment for the SEP together with clear delineation of who could access to the EZ. On the other extreme, participants had less coordination of effort and higher rent dissipation when the payment for the SEP was voluntary and without delineation of who could harvest in the EZ.

Cooperation, willingness to pay and rent dissipation

Participants were not advised on the way how to maximize their incomes, but they could infer it from the payoff table which they were provided with. During the period that they had available to discuss strategies how optimally allocate their quotas, they were able to find the best solution. However, sometimes all or some of the participants did not follow the agreed strategy, which varied depending on the incentives provided for each treatment.

The *Compulsory* treatment had lower rent dissipation relative to other treatments and this remained constant throughout the sessions without any improvement. This lower rent dissipation was a consequence of cooperation amongst participants and fishing effort coordination. The influence of voluntary co-operators was challenged by the influence of conditional co-operators. The latter group seemed to react to the perceived cost-benefit ratio of cheating and often behaved as free-riders, because the payment for the SEP was compulsory. Any deviation from the optimal level of cooperation implied costs that could be even higher than the revenues, and had to be paid by each participant. This cost acted like a punishment but controlled free-riding and promoted cooperation (Shinada and Yamagishi 2007). Self-interested participants alternately followed and broke the effort coordination agreement throughout sessions, which was reflected in fluctuating dissipation of rent. Compulsory payment had an implicit punishment when participants deviated from the effort coordination agreed, but even though this treatment signalled that cooperation was more profitable than free-riding, it was not the optimal treatment.

The policy behind of the *Compulsory* treatment was based on pure financial incentive, the carrot and the stick, and there were no non-financial incentives such as self-determination (Bowles 2008) or altruism (Fehr *et al.* 2002; Fehr and Fischbacher 2003). To achieve good outcomes, participants only had to comply with the rules. In contrast, under the treatments *By-use A* and *B* participants had the chance to choose whether or not to become involved in the SEP. Because this option implied acceptance of the enhancement cost, participants were more likely to be cooperative when they participated in the SEP. Both treatments initially had a high level of compliance in coordination of effort. Some participants who were less prone to be cooperative or resistant to paying the cost of the SEP, kept themselves out the SEP. Thus, they could exercise their self-determination and took the option of not cooperating. As the sessions progressed, willingness to pay and also compliance increased, which may be the influence of cooperative individuals. This type of voluntary cooperation has shown positive correlation to trust, attitude to helpfulness and fairness of strangers (Gächter *et al.* 2004). Therefore, the rules of these two treatments (treatment setting) provided conditions for common-interested participants to lead the economic exchanges to a cooperative equilibrium, where free-riding was controlled.

The treatments *By-use A* and *B* reached a similar level of cooperation and rent dissipation, basically because both treatments lead to cooperation providing exclusive access to the EZ. However, *By-use B* had the potential to further reduce rent dissipation as participants paid for the SEP as members of a cooperative. Cooperatives have the potential to reduce costs when they pool their fishing effort, through purchasing and selling power such as when buying supplies, and the removal of redundant vessels (Uchida and Baba 2008). These characteristics of cooperatives were not included in the simplified version of this treatment (*By-use B*) implemented in this experiment; however, it would be reasonable to expect lower rent dissipation, if cost had been pooled. There are examples where economic efficiency was increased by the introduction of cooperatives. In the Bering Sea Pollock fishery, the formation of Pollock Conservation Cooperative reduced cost and increased profitability by coordinating both harvesting and processing activities over the space and time (Wilen and Richardson 2008). In Alaska, the Chignik Sockeye Salmon Cooperative increased economic efficiency by reducing costs and also by providing shared inputs (Deacon *et al.* 2008).

In the *Voluntary* treatment, participants had low willingness to pay for the SEP and also low compliance with the effort coordination agreed amongst the group. There is known to be a relationship between expectations of cooperation and actual cooperative behaviour; higher expectations that others will cooperate will cause an individual to be more likely to be cooperative (Charness and Dufwenberg 2006). Under the *Voluntary* treatment, participants seemed to expect low cooperation from others, because there were no rules to provide any level of security that they would not be the 'fool' exploited by free-riders. Also there was no mechanism to charge participants for cost involved when they cheated on others. A similar conclusion was made from an economic experiment that investigated the influence of communication and heterogeneity of operators in a fishery in solving an assignment problem. In the absence of a structure for punishing offenders, co-operators reacted by reducing cooperation or defecting (Emery *et al.* 2015) This was consistent with the findings from a study based on a model of criminal behaviour and a survey to fishing industry in a unrevealed zone in United Kingdom; the probability of violation of quota restrictions decreased when the perceived risk of detection and expected level of fine increased (Hatcher *et al.* 2000).

Individuals may also react to quality of the provided service or good in choosing whether to cooperate as higher benefits increase the willingness to pay (Kanyoka *et al.* 2008; Snowball *et al.* 2008; Lee *et al.* 2014). Participants tended to allocate more effort into the EZ than was optimal and this behaviour was seen in the early sessions of the experiment. This behavoiur exacerbated the fear of funding the SEP and then being exploited by free-riders. Therefore, willingness to pay in a *Voluntary* treatment seemed to be influenced by a combination of two factors: expectation about others willingness to pay; and potential returns.

The influence of voluntary co-operators may drive others individuals to cooperate, to form social networks and may promote reciprocity and trustworthiness, all elements of social capital (Putman, 2000). This capital, contributed by voluntary co-operators, was not enough to encourage conditional co-operators to jointly reduce free-riding. It has been shown that rules were required to control extreme behaviour and provide the environment for cooperation (Clark et al. 2001; Fischbacher et al. 2001; Gächter et al. 2004; Shinada & Yamagishi 2007). Therefore, lack of rules around location of effort meant that payment for the SEP was too risky and that cheating was not punished, thus self-interested participants dominated the environment leading to rent dissipation.

In every treatment, examination of the digital communications between participants revealed peer pressure existed amongst participants when someone did not follow the agreed system for effort coordination. This factor was not include in the experimental design; however, it has been described as a kind of nonmonetary punishment, often strong enough to control self-interested actors (Masclet *et al.* 2003).

Trust and reciprocity

Trust is based on expectations of reciprocity where the trustors' decision involves aceptance of vulnerability (Evans and Krueger 2014). In the *Voluntary* treatment, players had low expectation of reciprocity. They avoided being vulnerable to free-riding and a low average number of participants paid for the SEP. This behaviour has been also observed in Australian abalone fisheries where industry-led resource management initiatives where carried out, including increase of size limits, consensus planning of the distribution of fishing effort, closing areas, and TAC reduction (Gilmour *et al.* 2011). In three out of five fisheries low level of percieved trust was associated with a low belief about operators' ability to cooperate. Lack of complaince in Swedish fisheries was highly discouraging to the complying fishers when offenders are not prosecuted, especially in cases when they confess the offence (Eggert and Ellegard 2003).

Participants also did not show reciprocity, allocating a significantly higher number of quota units in the EZ than the optimal. Some participants tried to encourage trust and reciprocity while the sessions were progresing so that economic yield could be increased; however, they failed to reach the optimal distribution of effort and participation in the SEP. As has been reported in the literature (Evans and Krueger

2014), expectations of reciprocity were influenced by the level of temptation to cheat plus a lack of rules that would lead to free-riders being punished or blocked. Unfavourable outcomes from round to round provided a negative feedback that prevented even more development of trust-reciprocity, since trustors pay a great deal of attencion to their own outcomes when they make decisions to trust strangers (Evans and Krueger 2014).

In the treatment *By-use A* and *B*, participants who were more prone to cooperate invested in the SEP, and initial outcomes were less affected by self-interested participants. Thus, from the beginning the outcomes were close to optimal, which was an incentive to trust and reciprocate in the following rounds. This was enhanced by repeated interactions, which increased cooperation between strangers (Andreoni & Miller 1993; Gächter & Falk 2002). Thus, given that trust relies on past behaviour (Resnick and Zeckhauser 2002), there was a positive feedback that reinforced trusting and reciprocating. However, the exclusive access to the EZ was fundamental to this result, considering that repeated interactions in the other treatments did not produce the same effect.

In the context of ITQ-managed fisheries, quota owners are theoretically expected to behave as resource stewards as a result from economic incentives (Wilen 2006). However, this cannot be generalized when additional resource management initiatives are applied, such as stock enhancement. Operators are able to identify opportunities for cheating (Fehr and Gächter 2002a) and it is difficult to design the right policy to control all aspects (Ostrom 1990); therefore, they cannot be exempted from developing trust and cooperation. In situations where the level of trust is low, fishers tend to ask for government regulations and enforcement of initiatives from industry (Gilmour *et al.* 2011). This may imply higher cost for fisheries and/or ineffectiveness of the management initiative as government fisheries agencies may be limited to monitor and inforce rules. Therefore, trust plays a role in reducing costs of fisheries enforcement (Pretty 2003; Grafton 2005), and the experimental economic approach provided a tool exploring the relative magnitude and direction of factors that lead to trust, reciprocity and cooperation. Management of fisheries may be thus assisted when cognisant of the design elements that create cooperative behaviour for better results from management initiatives.

5.6. Conclusions

Participants reacted differently according to the signals of different treatments and the behaviour of other participants as sessions were progressing. The presence of a compulsory payment provided some security that self-interested participants were going to be controlled, which reduced vulnerability of cooperative participants and increased the expectation of reciprocity. However, punishment was insufficient to promote cooperation, and other conditions for self-determination were required. Thus, cooperation, trust and reciprocity reached the highest level when individuals had the option of choosing whether to participate in the management measure or not. This required a mechanism that spatially blocked the actions of self-interested individuals, as was the case with the *By-use* treatments. Lack of trust and cooperation may increase fisheries management costs as higher level of monitoring and enforcement is required. The experimental economic approach provides a tool to assist management by providing information about factors that increase cooperative behaviour.

5.7. Appendices

5.7.1. Appendix 5.1. Payoff table in experimental dollars.

Total N of supported quotas in the zone	Enhanced Zone									Non-enhanced zone
	N° of people contributing to enhancement									
	0	1	2	3	4	5	6	7	8	
0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
1	$20	$21	$30	$30	$33	$34	$36	$37	$40	$20
2	$20	$21	$30	$30	$33	$34	$36	$37	$40	$20
3	$20	$21	$30	$30	$33	$34	$36	$37	$40	$20
4	$20	$20	$22	$30	$33	$34	$36	$37	$40	$20
5	$20	$20	$22	$30	$33	$34	$36	$37	$40	$20
6	$15	$20	$22	$23	$33	$34	$36	$37	$40	$20
7	$15	$20	$22	$23	$33	$34	$36	$37	$40	$20
8	$15	$20	$22	$23	$25	$34	$36	$37	$40	$20
9	$5	$20	$22	$23	$25	$34	$36	$37	$40	$20
10	$5	$10	$22	$23	$25	$30	$36	$37	$40	$20
11	$5	$10	$15	$23	$25	$30	$36	$37	$40	$15
12	$0	$10	$15	$18	$25	$30	$30	$37	$40	$12
13	$0	$0	$15	$18	$23	$30	$30	$37	$40	$9
14	$0	$0	$5	$18	$23	$30	$30	$31	$40	$8
15	$0	$0	$5	$8	$23	$30	$28	$31	$30	$8
16	$0	$0	$0	$8	$15	$30	$28	$29	$30	$2
17	$0	$0	$0	$0	$15	$22	$28	$29	$30	$2
18	$0	$0	$0	$0	$7	$22	$22	$29	$30	$2
19	$0	$0	$0	$0	$7	$22	$22	$27	$30	$2
20	$0	$0	$0	$0	$0	$16	$16	$27	$27	$2
21	$0	$0	$0	$0	$0	$16	$16	$21	$27	$2
22	$0	$0	$0	$0	$0	$8	$10	$21	$21	$2
23	$0	$0	$0	$0	$0	$8	$10	$15	$21	$2
24	$0	$0	$0	$0	$0	$0	$4	$9	$15	$2

Profit/quota

Cost of stock enhancement program was not included in this table, it was separately deducted ($10/player)

5.7.2. Appendix: Example instructions to participants

About this experiment

If you follow the instructions and make sound decisions, based on the information you are provided with, you may earn money that will be paid to you in cash at the end of the session.

What to do:

1. Read through the instructions carefully.
2. After reading the instructions, you will be taken to a short quiz that will test your comprehension of the instructions.
3. Correctly answering ALL of the quiz questions will give you a unique password that you can use to login to the experiment.

Overview of this experiment

The framework of this experiment is a rock lobster fishery under a quota management system. It implies that every fisher involved in the fishery is allocated with a number of fishing quota units. Every quota unit allows a specific amount (kg) of lobsters to be caught. For the purpose of this experiment it is not relevant how many kilograms of lobster are attached to each quota. What is relevant, is that every fished quota has associated a payoff that varies according a number of conditions.

In this fishery's context there is a **stock enhancement program (SEP)**, which involves translocation of rock lobster from zones where the fishing effort is negligible to other zone where the fishing effort is higher. As a result of the translocation two zones are generated, labelled as **Enhanced Zone** (**EZ**) and **Non-Enhanced Zone** (**N-EZ**). In this context, the experiment is concerned with the way people make decisions about where to go fishing and the associated impacts on their payouts in the future.

You are one of eight participants (fishers) **allocated with <u>three</u> fishing quota units**; therefore, **in the whole fishery there are <u>24</u> quota units**. Each participant has to make decisions about whether or not to pay to fund the SEP**. <u>You are allowed to fish in both the EZ and the N-EZ regardless you decided pay or not for the SEP.</u>**

Using the chat system implemented in the experimental software you will be able to communicate with other participants. All communication with other players must be with this system, <u>no other forms of communication are allowed</u>. There will be a number of rounds and during the course of each one you have to make these decisions.

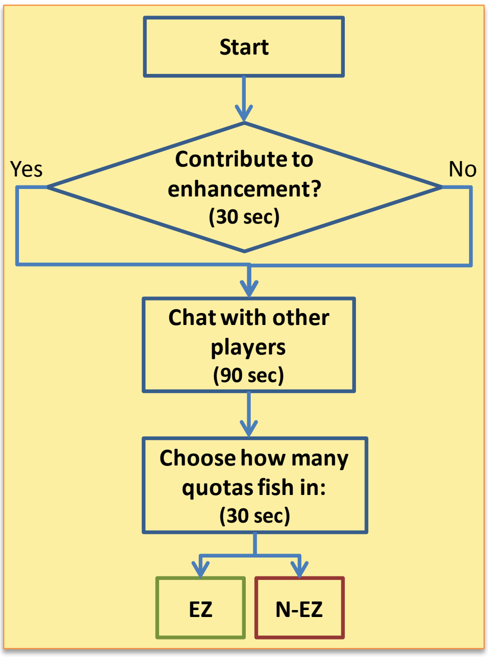
The SEP entirely depends on the industry funding and it is voluntary. This means that **each participant may choose or not to pay $10 to contribute to the SEP**. **Each participant can also choose in which area to allocate each one of the fishing quotas units (three)**. It implies that each one allowed to fish in the EZ, **even if someone has not contributed to fund the SEP**.

The payoff in the EZ gradually increases while the number of participants contributing to the SEP also increases. In both the EZ and the N-EZ there is a maximum number of quotas that return a maximum payoff, but once it is exceeded the payoff gradually decreases. There is an optimal number of quotas to be allocated in each zone that gives a maximum profit for each participant and the whole fishery. Each participant individually harvests his/her quotas.

In each round:

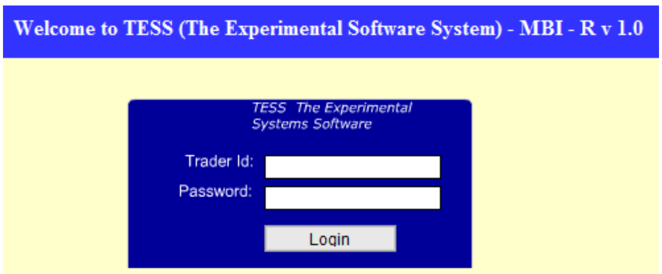
- You need to decide whether or not you will contribute for the SEP. You will have to make your decision in 30 secs.
- Once you decided contribute or not to the SEP, you are allowed to communicate with other players to discuss where allocate the quota units. You must use the chat software and you will have 90 secs to chat.
- Once you have chatted with the other players, <u>you have to allocate your quotas in the EZ and/or N-EZ.</u> You will have 30 secs to allocate your quotas.
- You individually harvest your quotas, accumulating the proceeds of each round.
- There will be a number of rounds.

A summary of the experiment is outlined in this flowchart:

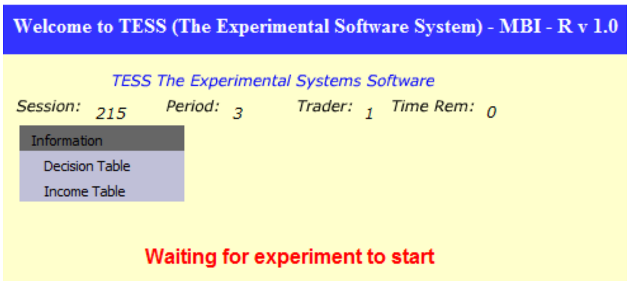


At the Start

Once you have successfully completed the quiz, you will be taken to the login screen where you will enter your Player Number (provided to you by the instructor) and Password (obtained when you successfully complete the quiz).



Once you have entered your Player Number and Password you will see the main experiment screen, as follows:



By clicking on the "information" tab you can access information about your choices. You can choose from the following menu selections:

Decision Table: This table provide you with:

- Information on the payment you will receive based on:
- How many participants contributed to the SEP and
- Total number of quotas that you and others allocated in each zone (EZ and N-EZ).
- The maximum number of quotas that give the maximum payment in each zone.
- The payoff reduction when the maximum number of quotas that return a maximum payoff is exceeded.

Income Table: This table provides you with information for each round about:

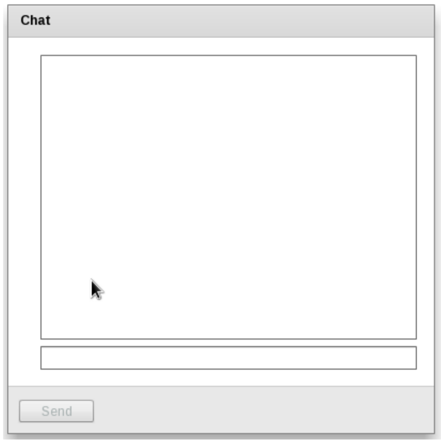
- Whether or not you chose to contribute to the SEP.
- Where you allocated your quotas, in the EZ and/or N-EZ.

- Where the group (including you) allocated its quotas.
- The round payoff per zone.
- Your round income.
- Your total income.

Chat Panel

Once you have successfully completed the quiz, you will also be able to access the chat system for the experiment through this log-in screen. Enter your Player Number (provided to you by the instructor) and click the Submit button.

Once you have entered your Player Number you will see the chat window as follows:



In order to send a message, click on the text bar at the bottom of the window and type your message. Then click the Send button.

During the experiment, you will **ONLY** be allowed to communicate through the chat software. Verbal communication is not allowed. Please comply with this rule to avoid confusion and wasting time. **Please note that you will only be able to chat with other**

participants during the decision period when the administrator (Player 9) notifies you that the chat window is open for communication through the message "*Start chat*" which will appear in your chat window and when the chat window is closed for communication the message "*End chat*" will appear. It is only during this period that you will be able to communicate with other participants.

Your message is prefaced with your Player Number, as shown above. Message history is shown in the chat window.

IMPORTANT NOTE: during the experiment your chat must confirm with the University Codes of Conduct. You cannot give any indication of your identity.

Decision Table

Clicking on the “DECISION TABLE” information tab in the main experiment screen will show you a table as in the screenshot below. This table shows **the payoff per quota according to the total number of quotas that all participants (including you) allocate in each zone**. Each participant has to decide whether or not contribute to the SEP, and then the whole group may discuss where everyone will allocate the quotas.

In order to make your decision you have to proceed like this:

- By knowing how many players will contribute to the SEP you will know what payoff column in the EZ you need to use (columns “0” to “8”, see the screen shot below).
- talking with other players you will know how many quotas will be allocated in each zone; therefore, you will know what row in the “quotas” column you have to use in each case.
- Intersecting the selected row and column you will able to know the payoff per quota in the EZ.
- To know the payoff per quota in the N-EZ you can proceed in a similar way. From the discussion with the other participants you will know how many quotas the group will allocate in the N-EZ. Therefore, you will know what row in the “quotas” column you have to use and intersect with the “N-EZ” column.

An example is shown below to illustrate how to use this table.

	Payoff per quota according to the total number of quotas allocated by all participants in each zone									
	Enhanced zone (EZ)									
	N° participants in the enhance program									*Non-EZ*
Quotas	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
2	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
3	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
4	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
5	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
6	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
7	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
8	$15.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$15.00
9	$5.00	$20.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$12.00
10	$5.00	$10.00	$25.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$12.00
11	$5.00	$10.00	$15.00	$28.00	$31.00	$33.00	$34.00	$35.00	$36.00	$12.00
12	$0.00	$10.00	$15.00	$18.00	$31.00	$33.00	$34.00	$35.00	$36.00	$8.00
13	$0.00	$0.00	$15.00	$18.00	$23.00	$33.00	$34.00	$35.00	$36.00	$8.00
14	$0.00	$0.00	$5.00	$18.00	$23.00	$30.00	$34.00	$35.00	$36.00	$5.00
15	$0.00	$0.00	$5.00	$8.00	$23.00	$30.00	$28.00	$31.00	$36.00	$5.00
16	$0.00	$0.00	$0.00	$8.00	$15.00	$30.00	$28.00	$31.00	$32.00	$2.00
17	$0.00	$0.00	$0.00	$0.00	$15.00	$22.00	$28.00	$31.00	$32.00	$0.00
18	$0.00	$0.00	$0.00	$0.00	$7.00	$22.00	$22.00	$31.00	$32.00	$0.00
19	$0.00	$0.00	$0.00	$0.00	$7.00	$22.00	$22.00	$27.00	$32.00	$0.00
20	$0.00	$0.00	$0.00	$0.00	$0.00	$16.00	$16.00	$27.00	$27.00	$0.00
21	$0.00	$0.00	$0.00	$0.00	$0.00	$16.00	$16.00	$21.00	$27.00	$0.00
22	$0.00	$0.00	$0.00	$0.00	$0.00	$8.00	$10.00	$21.00	$21.00	$0.00
23	$0.00	$0.00	$0.00	$0.00	$0.00	$8.00	$10.00	$15.00	$21.00	$0.00
24	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$4.00	$9.00	$15.00	$0.00

EXAMPLES ONLY:

Suppose that the players make the following decisions:

- <u>Four players</u> chose to <u>contribute</u> to the SEP.

- <u>Five players</u> chose to allocate <u>two quotas</u> in the EZ and <u>one</u> in the N-EZ.

- <u>Three players</u> chose to allocate <u>one quota</u> in the EZ and <u>two</u> in the N-EZ.

Then, the group's quota allocation is:

$$\boldsymbol{EZ} = 5\, player * 2\, \frac{quotas}{player} + 3\, players * 1\, \frac{quota}{player} = 13\, quotas$$

$$\boldsymbol{N-EZ} = 5\, player * 1\, \frac{quotas}{player} + 3\, players * 2\, \frac{quota}{player} = 11\, quotas$$

If you see the "quotas" column in the table and search the row "13" and you intersect it with the column "4" (four players contributing) you will see that the payoff is <u>$23/quota</u>. If you search row "11" you will see that the payoff in the "N-EZ" column is <u>$12/quota</u>.

Income Table

Clicking on the "INCOME TABLE" information tab in the main experiment screen will for each round show you (see the screen shot below):

- Whether or not you contribute to the SEP.
- Number of people (including you) contributing to the SEP.
- Where you allocated your quota units.
- Where the whole group (including you) allocated the total number of quota units (24).
- The payoff per zone, in experimental dollars.

- The income you received from your decision minus $10 by enhancement cost paid, in case you paid for that (“Your round income”), in experimental dollars.

- The payment you will receive per round in Australian dollars ("Your player income").

- At the top of the table, “Player’s Total Income” will show you your accumulated income in Australian dollars. It is the initial AU$10 plus player income per round.

Each experimental dollar is worth AU$0.0241. See the example below to understand how this table operates.

Player's Total Income: $11.16

Decisions on quota allocation										
Round	Contributing		Your quota allocation		Group's quota allocation		Round payoff		Your round income	Your player income
	Your decision	Group decision	Enhanced zone	Non-enhanced zone	Enhanced zone	Non-enhanced zone	Enhanced zone	Non-enhanced zone		
1	Yes	4	2	1	13	11	23	12	48	1.16

Values in the table are <u>only an example</u>

EXAMPLES ONLY:

Following the previous example, players (including you) allocated a total of <u>13 quotas in the EZ</u> and <u>11 in the N-EZ</u>, which is reflected in the income table (see the screen shot above). <u>Four players chose to contribute</u> to the SEP and <u>one of them was you</u>. From the decision table the round payoff is <u>$23 and $12 for the EZ and N-EZ</u> respectively, which also is reflected in the income table (see the screen shot above).

Suppose you were one of those players who allocated two quotas in the EZ and one in the N-EZ (see the screen shot above). Therefore:

$$\boldsymbol{Raund\ income} = 2\ quotas * \frac{\$23}{quota} + 1\ quota * \frac{\$12}{quota}$$

$$= \$58 - \$10(enhancement\ cost) = \$48$$

$$\boldsymbol{Player\ income} = \$48 * 0.0241 = AU\$1.16$$

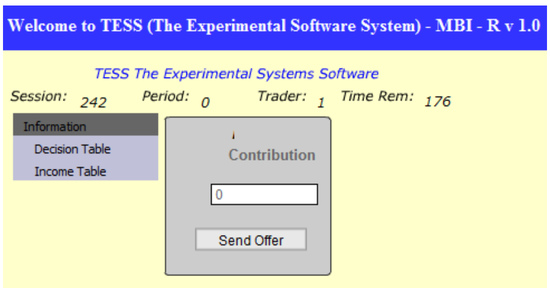
$$\boldsymbol{Total\ Player\ income} = AU\$10 + AU\$1.16 = 11.16$$

Note that **<u>you do not need to calculate your income</u>**; it will be automatically calculated for you.

Procedure

Step 1 – Making a decision about contributing or not to the SEP

For each round in the experiment you will be asked whether you will contribute or not to the SEP (see screenshot below). In order to make a decision, you will have to enter "1" if yes, you will contribute; and "2" if not, you will not contribute**. You will have <u>30 seconds</u> to make this decision.**

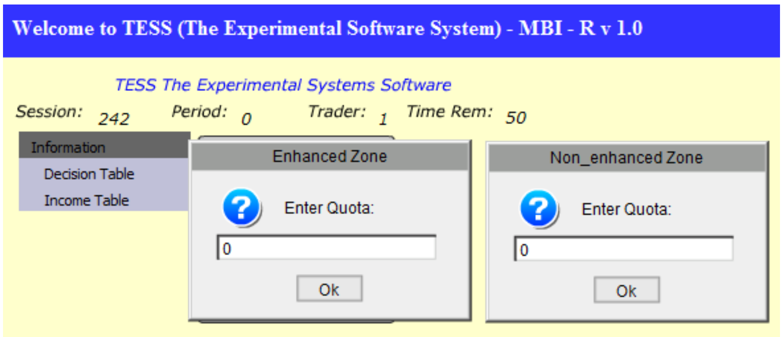


Step 2 – Coordination with other players where allocate the quota units

Once you have decided whether or not contribute you will have the chance to communicate with other participants through the chat software available (see the screen shot below). You can see how many participants (including you) decided to contribute to the SEP clicking on the “Income Table” tab. This is your chance to talk with other players to try to optimally allocate your quota units in the EZ and/or the N-EZ. **You will have <u>90 seconds</u> to chat.**

Step 3 – Making a decision about where allocate the quota units

Also you will be asked to make a decision regarding the number of quota that you will allocate in each zone. You must enter an appropriate value in each zone in such a way that **the total must be three**. This is to say that **you can fish in one zone 0, 1, 2 or 3 quotas and in the other you necessarily have to fish 3, 2, 1 or 0 respectively.** In order to have the decision table on the screen you need click on the “Decision Table” tab. **You will have <u>30 seconds</u> to make this decision.**



Step 4 – Review decisions and income earnings

On the conclusion of the decision period, your income table will be updated with a summary of both your and the group's fishing decision, number of allocated quotas in both zones, payoff per zone, your round income and total income.

Step 5 - Repeat of Steps 1-4

A number of rounds will be conducted. Decisions are only valid in the current round. The decision table will be the same in each round.

Step 6 – Conclusion of experiment

IMPORTANT: At the conclusion of the experiment you will be paid in cash the sum of the income you earned each round in addition to the turn up fee of AUD $10.

Experimental Rules

Before you start the quiz you are being paid to participate in this experiment. Failure to comply with these rules will result in the forfeiture of earnings from this session and you will not be allowed to participate in future sessions.

1. Talking is not permitted during the experiment: You can ONLY communicate with other players using the chat software.
2. You must not identify yourself when communicating using the chat software. When communicating you must conform to the University's code of conduct. In particular you must communicate in a manner that ***is free from harassment and discrimination.***
3. Only the experiment windows are permitted to be open during the experiment: You are not permitted to operate other software such as email or internet during the experiment
4. You may ask questions of the instructor during the experiment

Instructors can answer questions about procedures but cannot provide you with advice about decisions or trading. You must make decisions and develop strategies by yourself.

Now that you have read the instructions – please click on the quiz located on your desktop.

5.7.3. Appendix 5.2. Example of quiz to participants

The quiz uses the following decision table:

	Payoff per quota according to the total number of quotas allocated by all participants in each zone									
	Enhanced zone (EZ)									
	N° participants in the enhance program									*Non-EZ*
Quotas	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1	$20.00	$21.00	$30.00	$30.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
2	$20.00	$21.00	$30.00	$30.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
3	$20.00	$21.00	$30.00	$30.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
4	$20.00	$20.00	$22.00	$30.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
5	$20.00	$20.00	$22.00	$30.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
6	$15.00	$20.00	$22.00	$23.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
7	$15.00	$20.00	$22.00	$23.00	$33.00	$34.00	$36.00	$37.00	$40.00	$20.00
8	$15.00	$20.00	$22.00	$23.00	$25.00	$34.00	$36.00	$37.00	$40.00	$20.00
9	$5.00	$20.00	$22.00	$23.00	$25.00	$34.00	$36.00	$37.00	$40.00	$20.00
10	$5.00	$10.00	$22.00	$23.00	$25.00	$30.00	$36.00	$37.00	$40.00	$20.00
11	$5.00	$10.00	$15.00	$23.00	$25.00	$30.00	$36.00	$37.00	$40.00	$15.00
12	$0.00	$10.00	$15.00	$18.00	$25.00	$30.00	$30.00	$37.00	$40.00	$12.00
13	$0.00	$0.00	$15.00	$18.00	$23.00	$30.00	$30.00	$31.00	$40.00	$9.00
14	$0.00	$0.00	$5.00	$18.00	$23.00	$30.00	$30.00	$31.00	$40.00	$8.00
15	$0.00	$0.00	$5.00	$8.00	$23.00	$30.00	$28.00	$31.00	$31.00	$8.00
16	$0.00	$0.00	$0.00	$8.00	$15.00	$30.00	$28.00	$29.00	$30.00	$2.00
17	$0.00	$0.00	$0.00	$0.00	$15.00	$22.00	$28.00	$29.00	$30.00	$2.00
18	$0.00	$0.00	$0.00	$0.00	$7.00	$22.00	$22.00	$29.00	$30.00	$2.00
19	$0.00	$0.00	$0.00	$0.00	$7.00	$22.00	$22.00	$27.00	$30.00	$2.00
20	$0.00	$0.00	$0.00	$0.00	$0.00	$16.00	$16.00	$27.00	$27.00	$2.00
21	$0.00	$0.00	$0.00	$0.00	$0.00	$16.00	$16.00	$21.00	$27.00	$2.00
22	$0.00	$0.00	$0.00	$0.00	$0.00	$8.00	$10.00	$21.00	$21.00	$2.00
23	$0.00	$0.00	$0.00	$0.00	$0.00	$8.00	$10.00	$15.00	$21.00	$2.00
24	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$4.00	$9.00	$15.00	$2.00

Question 1 *How many quotas will I be allocated?*

A. 3

B. 6

C. 9

Your answer:

Question 2 *How many quotas are there in the whole fishery?*

A. 16

B. 24

C. 48

Your answer:

Question 3 *If I choose to contribute to the enhancement program and I fish three quota in the N-EZ, how many quotas do I have to fish in the EZ?*

A. 0

B. 2

C. 3

Your answer:

Question 4 *If I choose to contribute to the enhancement program and fish one quota in the EZ, how many quotas do I have to fish in the N-EZ?*

A. 3

B. 2

C. 1

Your answer:

Question 5 *If I choose to contribute to the enhancement program and I fish two quotas in the EZ and one in the N-EZ*

How much do I have to pay for the enhancement program?

A. $5

B. $10

C. $15

Your answer:

Question 6 *If I choose not to contribute to the enhancement program, can I fish any of my quotas in the EZ?*

A. Yes

B. No

Your answer:

Question 7 *What is the maximum number of quotas that the group should allocate in the EZ to obtain the maximum payoff per quota, if 5 people are paying for the enhancement program?*

A. 22

B. 15

C. 9

Your answer:

Question 8 *What is the maximum number of quotas that the group should allocate in the N-EZ to obtain the maximum payoff?*

A. 16
B. 12
C. 10

Your answer:

Question 9 *How much is the payoff per quota if 4 players choose to pay for the enhancement program and they allocate 16 quotas in the EZ?*
A. $23
B. $15
C. $7

Your answer:

Question 10 *How much is the payoff per quota if 0 players choose pay for the enhancement program and they allocate 8 quotas in the EZ?*
A. $15
B. $5
C. $ 0

Your answer:

Question 11 *How much is the payoff per quota if the group allocate 15 quotas in the N-EZ?*
A. $9
B. $8
C. $2

Your answer:

Question 12 *How much is the payoff per quota if the group allocate 13 quotas in the N-EZ?*
A. $15
B. $12
C. $9

Your answer:

Question 13 *If 4 players chose pay for the enhancement program and the quota unit allocation was:*

Operator	**Quota allocation**	
	EZ	**N-EZ**
Group (including you)	10	14
You	2	1

Question 13.1 *How much is the payoff per quota in the EZ?*

A. $15

B. $25

C. $33

Your answer:

Question 13.2 *How much is the payoff per quota in the N-EZ?*

A. $12

B. $10

C. $8

Your answer:

Question 13.3 *How much will I earn in the EZ? 4 player paid for the enhancement program and one of them was you ($10 cost)*

A. $50

B. $40

C. $30

Your answer:

Question 13.4 *How much will I earn in the EZ? 4 player paid for the enhancement program and I did not paid for that.*

A. $40

B. $50

C. $65

Your answer:

Question 13.5 *How much will I earn in the N-EZ?*

A. $8

B. $10

C. $15

Your answer:

5.7.4. Appendix 5.4. Optimal allocation of quotas in the enhanced zone

	Number of participants who paid for SEP		Optimal quota allocation limits	
Type of payment	Minimum	Maximum	Minimum	Maximum
Compulsory	-	8	-	1.87
By-use A and B	5	8	1.63	1.87
Voluntary	2	8	0.75	1.87

Chapter 6

General discussion

6.1. A thesis overview

The aim of this thesis was to quantitatively assess the performance of Individual Transferable Quota (ITQ) systems in meeting economic and social objectives by analysing fishers' behaviour and how it changed with variation in stock biomass. Firstly, this aim was addressed in the chapter two by exploring the TAC setting process in several ITQ managed costal fisheries in Australia and New Zealand. This involved analysis of whether the TACs were conservatively set to maximize profits as expected according to the economic theory around ITQs (Wilen 2006). These fisheries generally had histories that reflected good stewardship of resources, especially when fisher associations involved strong leadership who were supportive and able to drive decisions to stewardship. However, a non-trivial number of fisheries consistently showed lack of stewardship, setting TACs at levels that led fisheries to rent dissipation. Several factors were identified preventing stewardship, such as lack of understanding or acceptance of the rationale behind of ITQ systems. Fishers often considered the TAC to be a sustainability mechanism, misunderstanding its economic nature. Therefore, as soon as stock rebuilt, they lobbied for higher TAC, focusing on revenues rather than the higher profit that results from lower costs from higher catch rates. Lack of stewardship was also associated with heterogeneity of industry members' interests. For instance, some quota owners had a high discount rate as they needed immediate cash flow or were planning to exit the fishery. Sometimes the voting systems included non-quota owners, who do not benefit from the maximization of asset values and this structure contributed to lack of stewardship in TAC setting. It was concluded that implementation of ITQs does not ensure stewardship for resources. Additional conditions are required to reach this objective, otherwise, industry will continue to exhibit behaviours that ITQ systems supposedly eliminate. Therefore, it is fundamental that the mechanism that ITQs use to provide benefits are well understood by quota owners and managers. ITQ designs also need to recognise situations where stewardship will struggle to emerge in many situations, for instance, when the industry is dominated by operators who do not get benefits from the increase of market values and instead they profit form large catch (e.g. lease fishers and processors). Therefore, factors that may promote or eliminate good steward behaviour need to be considered when designing management systems and there can't be a blanket assumption that ITQs will produce positive outcomes.

In chapter three, changes in the permanent and temporary quota trade in the Tasmanian rock lobster fishery quota market were examined, during periods of both increasing and decreasing stock abundance. The Tasmanian rock lobster stock went through a period of stock rebuilding with biomass and catch rates increasing following the introduction of the ITQ system in 1998 until 2006. During a second period, the stock biomass decreased as a result of low recruitment (Linnane *et al.* 2010a), the TAC was under-caught and catch rate and quota lease price dropped (Gardner *et al.* 2011). The permanent quota trade was more active during the period of stock growth than during the period of stock decline. Quota owners appeared to increase their ownership due to expectations of higher rents, signalled by higher catch rates and quota prices. Thus they increased their scale of operation and/or become income supplementers or investors. The results also revealed that permanent transfer of quotas was not linked with quota owners' technical efficiency, instead it was driven by the financial capacity and to a lower degree by level of operations.

Disparate financial capacity is a driver in quota transfers and may lead to concentration. For instance, in the Icelandic cod fishery there was an unequal distribution of quota units, with units becoming concentrated in a small number of large companies. Small-scale vessel owners that still held units gradually needed to enter into contracts to fish for large quota owners (Pálsson and Helgason 1995). Financial capacity may also alter the expected transition of quotas to more technically efficient operators taking the form of vertical integration when, for instance, processor or bait suppliers are quota owners (Brandt and McEvoy 2006; Pinkerton and Edwards 2009). Also, exiting the fishery was associated with financial capacity rather than the technical efficiency as is theoretically expected with ITQs.

Variation in the stock biomass also affected the activity of the quota lease market, which increased during the period of stock increase but remained stable during the period of stock decline. It appeared that operators with a lower financial capacity and bargaining power were able to take advantage of a less competitive market during the stock decline period to expand their business (competition amongst operators to lease quota reduced because catch rates declined, so more fishing days were required to take the catch). An economic experiment showed that lease quota dependant fishers value resources differently to quota owners, because of different financial (Emery *et al.*in press). This experiment included a temporal fishery closure as a measure to solve assignment problems leading to rent dissipation. The temporal closure was less effective when the experimental fishery was dominated by lease quota dependant fishers, relative to when the fishery was dominated by quota owners. Therefore, it was concluded that decisions of lease quota fishers were influenced by their insecurity of tenure and lower profit as a result of the cost of leasing quota. This result was consistent with the current research where there was no link between operators' technical efficiency and amount of leased-in quota in the quota lease market (in contrast to the quota sale market). In conclusion, temporary and permanent quota markets are complex and affected by both trends in stock and also financial capacity of operators. As a result the theoretical trend of increasing efficiency in the fleet may not occur.

In chapter four, the connection amongst operators trading in the quota lease market was explored through a social network analysis approach. Variations in the quota lease trade network were also analysed in the context of changes in stock biomass. Social networks are a component of social capital and may be assessed by statistical network indicators. In this research the influence of fishing operational factors (level of catch, ownership etc.) on the operator's social capital was explored; and the influence of this capital on the market functionality measured by owned/leased quota balance and profit obtained by operators was also analysed. The structure and dynamic of the quota lease network changed with trends in the stock biomass. Operators increased their trading activity with an increase in the number and complexity of connections during the period of stock growth. This outcome appeared to result from the high catch and profit expectation signals delivered by a constraining TAC and higher lease prices. The trend of increasing complexity in the network persisted for the two first years of stock decline. It appeared that many operators, especially those more reliant on leasing, took the opportunity to expand their level of operation during this less competitive market with lower quota price. Expansion of ownership during periods of stock decline was also observed in the Queensland coral reef fin-fish fishery on the Great Barrier Reef. After a reduction in landings, the demand for leased quota decreased, but the market structure changes were not uniform relative to operators' category. Well-connected operators mainly reduced their number of lease-in connections because lease dependant operators were able to have their needs met by a smaller number of leasers-out.

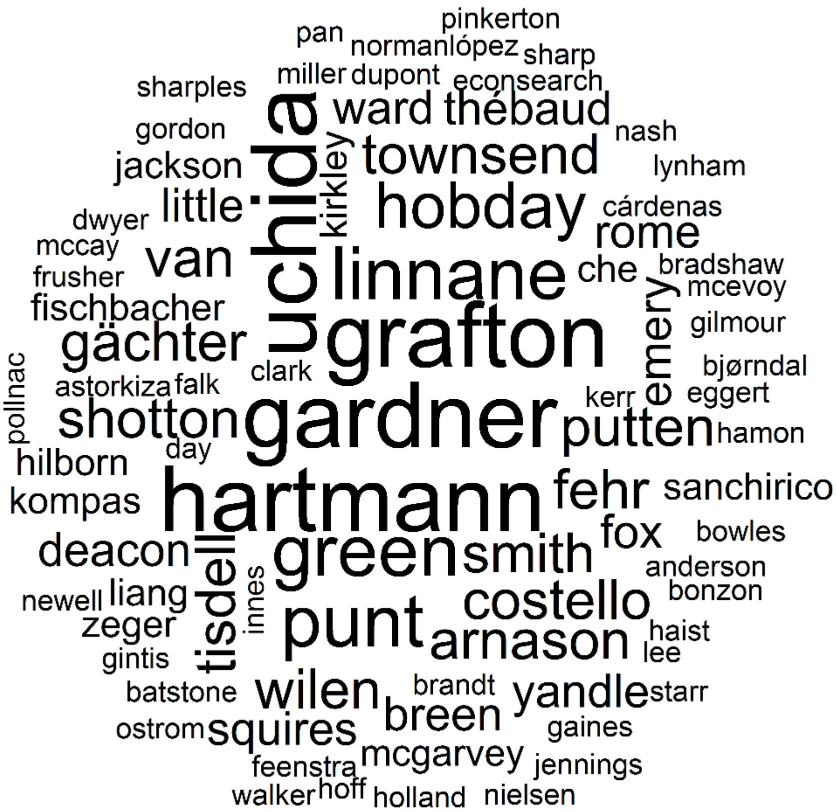
As higher effort and lower catch reduces profits, lease dependant operators responded to decreased stock biomass when the TAC became non-constraining. Networking of operators varied, with active operators that had higher catch developing greater linked networks for leasing in quota units. In contrast, investors and those operators not fishing at full capacity while still having high quota ownership had a high level of connections with well-connected operators. This network influenced the market functionality: active operators successful in increasing their profit by increasing their activity during the period of stock growth were less connected with well-connected operators. In contrast, investors tended to rely on a smaller number of well-connected operators. It appeared that the operators' quota lease trade activity was influenced by their financial capacity which led to different responses to temporal changes in stock productivity. Thus, market functionality involved an interplay between the financial success of active operators and investors and the stock status.

In the chapter five, an economic experimental approach was used to assess the potential for cooperative behaviour to reduce effort congestion in ITQ systems with the added complexity of a stock enhancement program (SEP). Because ITQ systems do not fully delineate where fishers may harvest their quotas, they will concentrate their effort in the most profitable patches. The experimental design included four treatments combining three types of payments for the SEP with either open or exclusive access to the enhanced zone (EZ). Income was either individually paid or equally distributed amongst participants as occurs in cooperatives. The results of the experiment showed different levels of fishing effort coordination according to the different incentives delivered by each of the treatments. For instance, the treatment that included voluntary payment together with open access led to a high level of free-riding in contrast with the treatment where the payment was compulsory. Regulations around payment allowed participants in the experiment to develop trust and reciprocity. Treatments that included a by-use payment combined with exclusive access to the EZ reached higher levels of trust and reciprocity and thus were most effective in preventing dissipation of economic rent. In these treatments there was no significant difference in the level of cooperation when the factor of sharing-income was included. Some real world complexity of cooperatives such as sharing of fishing activities was not included in this experiment to ensure participants could have a good understanding of the design before making decisions. Therefore, real world incentives from cooperation could be expected to be greater than in this experiment. Differences in cooperation between conditions of lease quota dependant dominated fisheries and quota owner dominated fishery disappeared when income sharing was enabled. In the context of ITQs, it was shown that stewardship promoted from the economic incentives cannot be generalized when additional resource management initiatives are applied (e.g. stock enhancement). Regulations cannot control all aspects and where there is opportunity for cheating, operators will identify these (Fehr and Gächter 2002a); therefore, incentives to develop trust and reciprocity amongst operators are required. Management of fisheries is thus assisted by understanding factors that lead operators to develop attributes of trust and reciprocity and could affect the design of management systems for better results. The experimental economic approach provided a tool for exploring the relative magnitude and direction of the effect of resource management initiatives.

This thesis emphasised the outcome of ITQ systems in management of marine resources will vary according to differences amongst fisheries and amongst operators' business structure within those fisheries. Management objectives are most likely to be met when there is consideration of operators' behaviour, as was shown for the case for stewardship promotion by ITQs. Similarly, the reaction of operators varied according to their business characteristics and to stock biomass changes. Understanding these could refine the design of ITQ systems to avoid rent dissipation. Finally, achieving fishery objectives with ITQ management involved more than pure economic incentives with factors such as trust and cooperation also important. Understanding these factors is especially important when resource management decisions are initiated and/or controlled by the industry, as can occur in co-management systems.

Appendices

Appendix A
References



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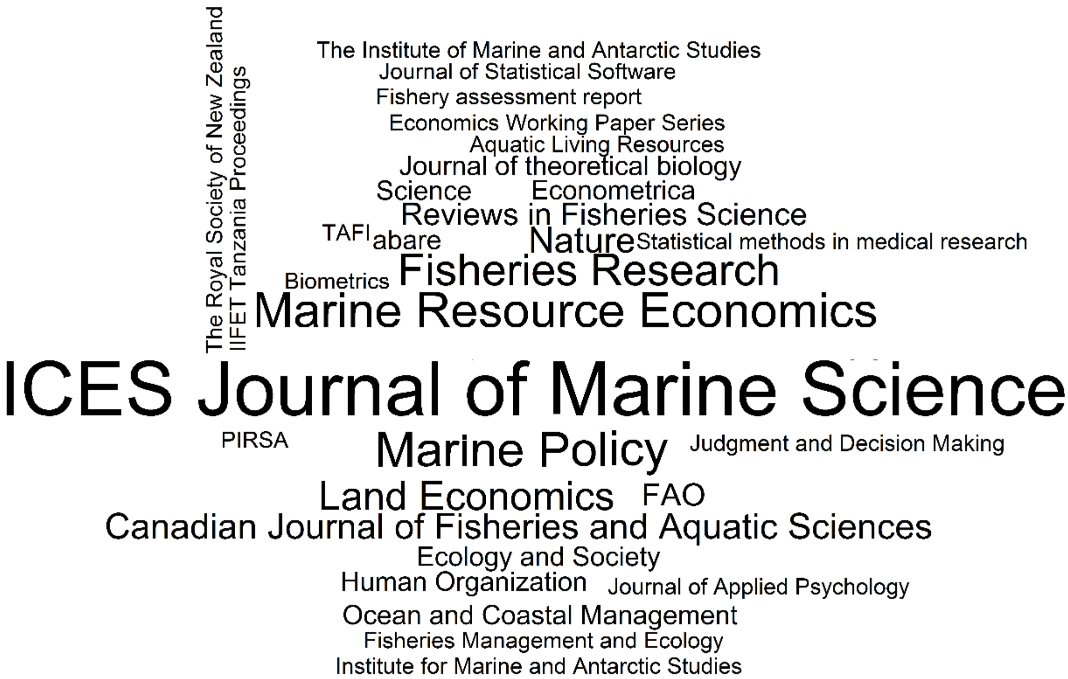
Appendix B

Published paper



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